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THE FACTORS OF COST OVERRUN IN THE WEAPONS ACQUISITION PROCESS

by

Thomas Joseph Faleskie

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THE FACTORS OF COST OVERRUN IN THE WEAPONS ACQUISITION PROCESS

BY

Thomas Joseph Faleskie
Bachelor of Science
University of Scranton, 1958

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Business Administration of The George Washington
University in Partial Fulfillment of the
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Master of Business Administration

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Thesis directed by
Dr. Daniel D. Roman
Professor of Business Administration

Thesis
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CHAPTER I

INTRODUCTION

Discussion of the Problem

Within the last two years, considerable attention has been focused on the problem of "cost overrun" or "cost underestimation," in Department of Defense expenditures. In particular, this notoriety has centered on the advancing price tags attached to certain weapons systems and programs. In the past several years, enormous overruns ranging from 300 to 1000 percent have occurred.[1] This illustrates the problem. Specifically, the tendency in calculating weapons systems costs has been to underestimate.

Probably the loudest congressional outcry resulted from the Air Force contract with Lockheed Aircraft Corporation for procurement of the giant C-5A transport. Senator William Proxmire and the Joint Subcommittee on Economy in Government, pointed out that the projected costs of the entire contract package have risen from $3.4 to $5.3 billion dollars.[2]

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[1] John H. Rukel, "Research and Development Contracting, Policies and Problems," in Research and Development Contracting, (Washington, D.C.: Federal Publications Inc., 1963), p. 23

[2] "The Inflated Case of the C-5A," Armed Forces Management, July 1969, P. 71

Cost overrun is not just a problem of recent years. Historically, it is worth noting that funding problems had their roots in times preceeding the first United States Naval Fleet. On March 27, 1794, Congress authorized the building of six frigates at a total cost of $688,888.32. The problems incident to the construction of these frigates were numerous, and not unlike the problems we encounter in weapons system acquisition today. It was intended that the six frigates would be afloat in 1795. However, the Secretary of War's report to the House of Representatives in 1794, concerning the progress on the construction of the ships, told of late delivery. In his report, he noted,

> That everything, if not to be created, must be modified. The wood of which the frames are to be made is standing in the forest; the iron for the cannon lying in its natural bed; and the flax and hemp perhaps in their seed.

It soon became apparent that only enough live oak could be delivered to sustain construction of two frigates. Construction had to be suspended on the remaining ships. Sources of supply were few and far between. Funds were reprogrammed to cover excess costs over the original estimates. The actual cost came to $926,267.55 for just three frigates, when six had been estimated to cost $688,888.32. As a result, there was a Congressional

inquiry into the "apparently enormous" cost of building three frigates.[1]

In more recent times, the Department of Defense acknowledged in December 1969, that the projected cost overruns on 35 major weapons systems amount to nearly $20 billion. The average growth in costs among these systems cited was approximately 27 percent against a base-line estimate of $74 billion. Table 1 lists eight selected weapons systems and compares the base-line cost estimates with the current estimates. The total cost overrun is expressed as a percentage of the base.

Defense managers are worried about the size of specific overruns. For example, the total overrun may amount to as much as 395 percent in the case of the Westinghouse Mark 48 torpedo. A June 1964 estimate amounted to $655 million. The total estimated cost is now $2.8 billion.[2]

In two Navy programs, the DD-963 destroyer and the DXGN nuclear frigate, the actual contracting state has not yet been reached and the costs have risen $1.7 billion and $1.5 billion respectively. Inflation has been cited as the prime cause for the rise in costs. Whether or not inflation is really the reason remains to be seen.

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[1] Commander, Naval Supply Systems Command, "Did you Know," Navy Supply Corps Newsletter, March 1970, p. 70

[2] "Taking the Defensive on High Arms Costs," Business Week, December 6, 1969, p. 70

TABLE 1

THE BIG COST OVERRUNS IN DEFENSE WORK

System	Millions of dollars		
	Baseline Estimate	Current Estimate	Percent Increase
F-111 Fighter Bomber	$3,267	$7,278	122.8%
Mark 48 Torpedo	655	3,241	394.8
DD-963 Destroyer	1,738	3,422	96.9
F-15 Fighter	6,039	7,700	27.5
C-5A Transport	3,413	5,004	46.6
DXGN Nuclear Frigate	3,335	4,875	46.2
Poseidon Missle	4,272	5,651	32.3
SRAM Missle	421	1,470	249.2

Source: "Taking the Defensive on High Arms Costs," *Business Week*, December 1969, p. 70

The foregoing examples of cost overrun are not isolated or unusual cases. The cases cited in Table 1 are selected to highlight certain programs where costs have exceeded the original estimates by more than $1 billion.

This discussion establishes that a severe problem exists, and that it is more widespread than was commonly supposed. From the record of major systems costs, it might be inferred that this problem is extended to the lesser programs which, for one reason or another, do not find themselves under critical scrutiny from Congress and the public.

Discussion of Specific Aspects of the Problem

Acquisition of a weapons system is not to be compared to the purchase of an automobile. The latter implies a fixed, or nearly fixed cost. Procurement of a weapons system is preceeded by research, development, test and evaluation. In each stage there exists an element of uncertainty. This uncertainty may take the form of technological requirements, performance specifications, time, labor and materials availability, or production capacity. Each uncertainty, when related to cost, tends to produce an upward effect on final costs. In other words, the government does not simply purchase a system at some stated cost.

The introduction of any uncertainty, generally requires a prediction. In systems acquisition, the heart of the problem is the adequacy of cost prediction. The inference is that a faulty or inadequate estimate of the program costs tend to result in cost overrun. The elements of the problem are the specific uncertainties or factors that contribute in some way to the overall situation.

A review of the Department of Defense record of cost estimation during the fifties, indicates an apparent bias toward underestimation.[1] The degree of underestimation and the variance of estimation error, seem to be related to the earliness of the estimate, and also the type of program involved. Differences between early estimates and final costs have been smaller for systems where attempted technical advances were modest. These included non-combatant ships, and cargo aircraft. Errors in early estimates seem larger for new combat aircraft with advanced radars, communications, and weapons. The same is true for advanced engines and guidance systems.[2]

---

[1] A. W. Marshall and W. H. Meckling, "Predictability of the Costs, Time and Success of Development," The Rate and Direction of Inventive Activity; Economic and Social Factors, National Bureau of Economic Research, (Princeton, N.J.: Princeton University Press, 1962), pp. 461-475

[2] Norman V. Breckner and Joseph W. Noah, "Costing of Systems," in Defense Management, ed. by Stephen Enke, (Englewood Cliffs, N.J.: Prentiss-Hall, Inc., 1967), pp.56-57

Even though the relationships between the degree of system sophistication, cost, and time, seem apparent, the extent of the overrun "factor" is virtually unknown. Prior studies however, have uncovered certain characteristics of cost behavior in systems acquisition. Frederic M. Scherer, Professor of Economics at the University of Michigan, in testimony before the Subcommittee on Economy in Government, cited trends in weapons systems costs that occurred in the past. In a study of 12 major U.S. weapons systems, conducted eight years ago, it was found that actual systems costs turned out to be roughly three times the originally predicted costs. That is, on the average, the overrun factor was on the order of 220 percent.[1]

In the F-111 program, for example, the actual costs range from 2.2 to 3.0 times the original cost estimates. This is practically the same factor observed by Scherer and his associates. While an overrun factor of 2.0 to 3.0 might not be representative of all systems acquisitions, the studies nevertheless highlight the problem experienced in cost estimating.

With the correlation between early estimation errors and increasing costs, it may be argued that the cost estimate should be developed only after the unknowns are resolved. It

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[1] U.S. Congress, Joint Economic Committee, The Military Budget and National Economic Priorities, Hearings, before a Subcommittee on Economy in Government, 91st Congress, 1st Sess., June 9, 1969, p. 378

is noted, however, that early estimates are required because development resources are constrained. Even if the intention is to buy partial or sequential development on a system proposal, it must be selected from a wide range of choices.[1] The cost estimate is one aid in preliminary evaluation of developmental proposals. As estimates are revised when confronted with experience, they become credible for analyses leading to production decisions.

Good cost estimates are extremely important, not only because weapons systems are becoming more costly, but because there are so many systems competing for consideration. In choosing between various military systems, cost is one element of choice that cannot be ignored. The cost of one proposal must be compared with the cost of others to intelligently weigh costs and benefits. The strategic value of the choice or trade off may depend on the cost estimate. The problem then becomes one of accurate prediction while faced with uncertainty. Intelligent cost estimating is at least as important in military management and decision making as in any other sector of government activity or in private business enterprise.

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[1] Charles J. Hitch and Roland N. McKean, The Economics of Defense in the Nuclear Age, (Forge Village, Mass.: The Murray Printing Co., 1965), p. 105

Statement of the Research Question

The foregoing discussion of cost overruns and the degree of estimating error in development and production costs leads to the specific research question in this study. Can the factors contributing to the cost overrun problem be isolated and analyzed to develop greater certainty in systems acquisition cost prediction?

An affirmative reply to the question would assume that, first, throughout the systems acquisition process, certain relationships of activity to cost are present that will generally hold true throughout. Second, that knowledge of these relationships, together with intelligent analysis, can be applied to cost estimating to reduce the degree of predictive error.

The Scherer testimony before Senator Proxmire's subcommittee would suggest that there may very well be factors inherent in systems procurement that lead to cost overrun.[1] Further, these factors may occur as a multiplier of the original cost estimate. It is the task of this study to attempt to identify these factors and determine if they can be applied to the estimating process to narrow the degree of error.

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[1] U.S. Congress, Joint Economic Committee, Op.Cit., p. 378

Scope, Limitations, and Methodology

Scope

The study will concentrate on three broad areas of the problem. First, a discussion and critical analysis of the Department of Defense contracting practices. These generally consisting of fixed price and cost reimbursement type contracts. A discussion of intangible relationships, such as government and contractor optimism, will be included. Second, an analysis of national economic trends from 1958 to the present time, which might contribute to the problem. Finally, a discussion and analysis of the cost prediction tools available to the estimator. These tools include techniques of regression analysis, estimating relationships, industrial engineering methods, and analogy.

In order to put the study into its proper perspective, the research question could be further defined in terms of the study scope as follows: "Are there certain factors inherent within the Department of Defense contracting process, the economic trends of the nation, and the predictive methods available to the estimator, that have a bearing on whether or not a program exceeds its targeted cost?" "If so, what are they?" Finally; "If these factors are known, can they be analyzed and the results used to reduce the seemingly inherent error in cost prediction?"

Limitations

For purposes of the study, the systems acquisition process is divided into four stages. These are research and development, test and evaluation, manufacture and procurement, and operational. This process division is sufficient to encompass the entire life cycle of a particular system. Discussion of factors leading to cost overrun will be limited to the first three. Mention is made of the operational stage at this point but will henceforth be disregarded. The rationale to disregard this stage should become apparent in the following paragraph.

To concentrate on specific factors contributing to cost overrun, it is necessary to define the type of "costs" to be the subject of prediction. Costs are divided into "recurring" and "non-recurring."[1] Non-recurring costs belong to the research and development and initial investment for procurement stages in the acquisition process. Recurring costs fit into the operational stage of systems acquisition.[2] The study will consider only the non-recurring costs associated with defense procurement. That is, funds used for research, development, test, and the actual procurement of the system. As previously stated, the operational stage would be disregarded.

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[1] J. P. Large, ed., "Concepts and Procedures of Cost Analysis," RM-3589-PR, The Rand Corporation, June 1963

[2] Breckner and Noah, Op. Cit., p. 49

It should be apparent that costs in the operational stage are of a recurring nature and not the focus of this study.

To provide an overview of the major cost elements within a system, Table 2 lists a typical framework describing recurring and non-recurring costs.

A final limitation is placed on the study, to the extent that it will concentrate primarily on the acquisition of aircraft and aircraft weapons systems. Much, though not all, of recent public attention to the cost overrun problem, has been directed to aircraft procurement. The most noteworthy example is the C-5A transport. Congressional inquiry into the C-5A overrun has brought out a great deal of information concerning the problem. That information will be used to present evidence of cost overrun contributory factors.[1]

Methodology

Project Design.--Though the study is limited primarily to the procurement of aircraft systems, an attempt will be made to generalize the conclusions that emerge. Inductive logic is employed to show that cost overrun factors may be applicable to the procurement of any system. Likewise, the methods of cost prediction and their problems, may be applicable to acquisitions other than aircraft.

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[1] U.S. Congress, Joint Economic Committee, The Military Budget and National Economic Priorities, Hearings, before the Subcommittee on Economy in Government, 91st Congress, 1st Sess., 1969

TABLE 2

TYPICAL CLASSIFICATION OF WEAPONS SYSTEM COST ELEMENTS

A. Non-Recurring

I. Research and Development

1. Preliminary Research and Design Studies
2. Design and Development (Of Subsystems)
3. System Test (Of Complete System)

II. Initial Investment

1. Prime Mission Equipment
2. Support Equipment
3. Initial Spares, Spare Parts and Stocks
4. Initial Training
5. Initial Training
6. Military Installations

B. Recurring

III. Annual Operations

1. Pay and Allowance
2. Equipment and Installations Replacement
3. Equipment and Installations Maintenance
4. Replacement Training
5. Consummables (e.g. fuel, oil, etc.)
6. Recurring Travel, Transportation, and Miscellaneous

Source: Norman V. Breckner and Joseph W. Noah, "Costing of Systems," Defense Management, ed. by Stephen Enke, (Englewood Cliffs, N.J.: Prentiss-Hall, Inc., 1967), pp. 56-57

Four steps are involved in attempting to isolate cost overrun contributing factors and show their effect on cost prediction. First, an examination of present and past Department of Defense contracting practices, with concentration on the aspects which may create an overrun tendency. Second, a critical analysis of present cost predicting tools aimed at the points least susceptible to control by the estimator. Third, an examination of the relationship of economic trends to the systems acquisition process, and their effects on cost. Finally, the collection and listing of overrun factors that emerge, together with a deductive analysis of effects that their control would have on cost prediction.

Data Sources.--Large quantities of information directly relating to the problem were brought out by the Subcommittee on Economy in Government from January to November of 1969. The study relies in part on testimony of noted economists and personnel within the Defense Department, such as A. E. Fitzgerald, former Deputy for Management Systems, Department of the Air Force.[1]

Data is also drawn from numerous RAND Corporation studies in cost analysis, cost prediction, procurement contracting, and research and development costs. Further, data is obtained from a variety of related books, periodicals and reports, both from within and outside the Department of Defense.

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[1] U.S. Congress, Joint Economic Committee, Op. Cit., pp. 595-616

CHAPTER II

A DISCUSSION AND CRITICAL ANALYSIS OF DEPARTMENT OF DEFENSE CONTRACTING METHODS

Defense Contracting Methods

The weapons acquisition process involves three broad types of contracts. These are the firm-fixed-price (FFP), cost-plus-fixed-fee (CPFF), and incentive contracts. The Armed Services Procurement Regulations groups the various contract types into two main classes based on their compensation features. These are: (1) fixed price contracts, and (2) cost reimbursement contracts. This classification will be used to present an explanation of the various contracts.

Fixed Price Contracts

This contract provides for a price that is not subject to adjustment by reason of cost experience of the contractor during performance. Reimbursement may include a certain sum of money per unit delivered or consist of a lump sum payment after contract completion. Such a contract is appropriate where definite systems specifications are available and there is a highly reliable basis for pricing. It is generally used

to procure standard commercial items or those military items where accurate production and cost information is available. Much of the more routine construction falls in this category.[1]

In practice, the two conditions appropriate for a fixed-price contract do not always remain static. Specifications and costs are usually subject to change over the long run and it is necessary to provide for price adjustments under certain conditions. These modifications to the firm-fixed-price contract will be discussed.

Fixed Price with Provisions for Escalation.--Adjustment provisions are included in this fixed-price contract. Upon occurrence of specified contingencies, the contract price may be adjusted either upward or downward. A reasonable ceiling is usually imposed on price increases but there is no floor limiting downward price adjustments.[2] Increasing costs due to wage negotiations or rise in material prices during the contract term would provide a basis for escalation provisions.

Fixed Price with Redetermination Provisions.--Price redetermination provisions are attached to the contract and

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[1] Merton J. Peck and Frederic M. Scherer, The Weapons Acquisition Process, (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1962), p. 61

[2] ASPR 7-106, 107 prescribes various circumstances and escalation clauses that may be used.

may be negotiated either at stated intervals or retroactively upon contract completion.[1]

Under periodic renegotiation, a firm fixed price is established initially. Future price redetermination provisions are included. These provisions state specified intervals at which price adjustments may be made. In practice, these intervals are generally one year.[2]

When price negotiation is to be made upon contract completion, a price ceiling is established initially. The final price is negotiated after the completion of the contract.

Fixed-Price Incentive Contracts (FPIF).--This contract consists of a negotiated target cost, a target profit based on target cost, a price adjustment formula, and a maximum price ceiling. Final cost is negotiated upon completion of the contract and the price adjustment formula is used to determine the profit.

Contractor profits are increased as costs are decreased below target. Similarly, as costs overrun the target, profits decrease. The incentive to the contractor revolves around the price adjustment formula whereby he may increase profits by cutting actual costs under the target. The formula is constructed to provide a sharing of cost reduction benefits

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[1] ASPR 3-404.5 - .7 prescribes the conditions for use of price redetermination clauses.

[2] Gilbert A. Cuneo, Government Contracts Handbook (Washington, D.C.: Machinery and Allied Products Institute and Council for Technological Advancement, 1962), p. 146

and increasing cost burden between the contractor and the Department of Defense. Government liability is limited by the negotiated ceiling price. Table 3 illustrates a Fixed-Price Incentive Fee Contract with cost control incentives.

Cost Reimbursement Contracts

This major class of contract types provides for payment of all allowable costs incurred in the performance of the contract. Allowable costs in contract performance are specified in the Armed Service Procurement Regulations.[1] Examples of unallowable costs are advertising expenses, donations, interest, and other financial costs.

Cost-Plus-Fixed-Fee Contract (CPFF).--This contract provides for the payment of a specified fee in addition to all allowable costs. The amount of the fee is fixed by law and the actual costs incurred in the performance of the contract do not change it.

The fee for research and development, or experimental work is limited by law to 15 percent of estimated costs. The maximum fee for other work under this type contract is 10 percent. By regulation however, the Department of Defense has limited these fees to a maximum of 10 percent for R&D and 7 percent for other work.[2]

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[1] ASPR 15, part 2

[2] Frederick T. Moore, "Incentive Contracts," Defense Management, ed. by Stephen Enke (Englewood Cliffs, N.J.: Prentiss-Hall, Inc., 1967), p. 215.

TABLE 3

FIXED-PRICE-INCENTIVE-FEE CONTRACT

(Cost Control Incentive)

	Negotiated
Target Cost	$2,000,000
Target Profit (7%)	140,000
Target Price	$2,140,000

Price Adjustment Formula:		
	DOD:	75%
	Contractor:	25%

Price Ceiling (125% of Target Cost)	$2,500,000
Profit Ceiling (12% of Target Cost)	240,000

	Actual
Actual Cost	$1,800,000
Cost Underrun	200,000
Contractor Profit Target	140,000
25% of Cost Underrun	50,000
Total Profit	$ 190,000
Government Cost:	
Actual Contractor Cost	$1,800,000
Contractor Profit	190,000
Total Cost to Government:	$1,990,000

Note: A cost overrun would involve the same calculations but would result in a decrease in contractor profit and increase in government cost.

Cost-Plus-Incentive-Fee Contract.--A target cost, target fee, and fee adjustment formula are utilized in this type contract. Additionally, minimum and maximum fees are determined. The fee adjustment formula is applied to the total costs to determine the contractors fee upon completion of the contract. When actual costs fall below targeted costs, the result is a higher than targeted fee. The opposite is true as well. The final fee, however, may not fall outside the negotiated maximum and minimum limits.

It is appropriate to use this type of contract where the range of cost estimates is large, but not so large as to justify the use of a cost-plus-fixed-fee contract. There must also be a reasonable basis to assume that the contractor can control a significantly large portion of total costs through efficient management.

Other Contracts.--In addition to the contract types mentioned, there are other types such as cost sharing, cost, time and materials, labor-hour, and open contracts. These are of minor importance to this discussion and will not be elaborated upon.

Background of Department of Defense Contract Preference

Prior to World War II, there were only two main contract types. These were the firm-fixed-price (FFP) and the

cost-plus-fixed-fee (CPFF). The CPFF was much more widely used to procure military hardware. Incentive contracts were introduced primarily as a substitute for the CPFF contract.[1]

During the 1950's, the use of the CPFF contract increased steadily and accounted for approximately 40 percent of new contract dollars. By 1966, however, that figure had decreased to about 5 percent. The incentive contract had accounted for virtually all of the difference. When the decline in CPFF contracting began, the slack was taken up by CPIF and FPIF contracts. Since 1964, however, FPIF usage has increased only slightly, while CPIF usage has fallen substantially.[2]

A Department of Defense drive to increase the use of fixed price contracts has produced a rapid turnabout, particularly in Air Force procurement. By 1966, at least half of Air Force procurement funds were obligated by firm-fixed-price contracts, yet these contracts accounted for only 15 percent of research and development purchases and only 9 percent of complete systems purchases.[3]

Complete systems purchases are the major concern of this discussion. To isolate contributing factors to cost

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[1] _Ibid._, p. 214

[2] Gerti L. Brunner and George R. Hall, _Air Force Procurement Practices (1964-1966)_, RM-5439-PR (Santa Monica, Calif.: The Rand Corporation, April 1968), p. 15

[3] _Ibid._, p. 15

overrun in systems acquisition, primary emphasis is placed on contracting methods chiefly employed in the past and present. The current trend in systems acquisition is to utilize the incentive contract forms, such as FPIF and CPIF.[1] Table 4 summarizes the Air Force dollar outlay by contract type for research and development, and complete system purchases for fiscal years 1964 through 1966. In research and development, the CPIF tends to be the contract type most often employed. Similarly, complete systems acquisitions seem to be made mostly with the FPIF contract.[2]

Critical Assessment of Government Contracting

The Weaknesses of Cost-Plus-Fixed-Fee

The distinguishing features of cost-plus-fixed-fee (CPFF) contracts are, that the government agrees to pay a fixed target profit, absorb costs in excess of target costs, and places relatively little restriction on total costs. These characteristics appear to offer a reverse incentive for the contractor to control costs. Since the fee is a fixed amount, incurring additional costs affects profit only as a decreasing percentage of total cost. Should the contractor

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[1] FPIF includes fixed price with escalation provisions, and fixed price redetermination contracts.

[2] Brunner and Hall note that: "The contractor who receives the R&D contract for a weapons system will usually receive the follow-on contract for systems hardware. . . even though separate contracts may be let for each stage," Op. Cit., p. 27

TABLE 4

AIR FORCE PROCUREMENT BY PRODUCT GROUP AND TYPE OF CONTRACT, FISCAL YEARS 1964 THROUGH 1966

(In $ Millions)

Product Group	Fiscal Year	FFP	FPIF	CPIF	CPFF	MISC	TOTAL
Research and Develop.	1964	190.8	579.9	1643.1	814.8	32.9	3261.6
	1965	279.5	491.1	1065.1	526.9	9.45	2372.2
	1966	386.0	778.7	1083.7	326.3	18.74	2593.64
Complete Systems	1964	112.5	1480.2	109.3	85.4	----	1787.6
	1965	201.4	1388.9	116.1	47.1	.1	1753.7
	1966	171.6	1551.7	114.2	48.1	.3	1886.1

Source: Gerti L. Brunner and George R. Hall, Air Force Procurement Practices (1964-1966), RM-5439-PR (Santa Monica, Calif.: The Rand Corporation, April 1968), p. 15

come under pressure from the government to meet a work deadline, the tendency has been to relax cost controls to meet the schedule.

Normally, should the contractor overrun the estimated cost, profit remains constant but decreases as a percentage of the total cost.[1] It has been argued that this decreasing rate of profit in an overrun environment, still provides an incentive for the contractor to control costs. Nash curtly dismisses this argument as follows:

> This (decreasing rate of profit) is surely a minimum incentive and most commentators have agreed that this type of contract provides a minimum incentive in the cost area.[2]

Moore notes that it is fairly common for contractors to benefit from increasing costs with increasing fees. The parties to the contract tend to use it as a means to order additional work for which the contractor is entitled to additional profit.[3]

---

[1] The profit can increase if the original work scope is changed and there are subsequent negotiations covering the change in program concept.

[2] Ralph C. Nash, Jr., "Cost Plus Fixed Fee Contracting," in Research and Development Contracting, (Washington, D.C.: Federal Publications, Inc., 1963), p. 109

[3] Frederick T. Moore, Military Procurement and Contracting: An Economic Analysis, RM-2948-PR (Santa Monica, Calif.: The Rand Corporation, June 1962), p. 35

In a 1962 report, government officials criticized the disadvantages of the CPFF contract as follows:

> It (CPFF contract) provides little or no incentive for private managers to reduce costs or otherwise increase efficiency. Indeed, the cost-plus-fixed-fee contract, in combination with strong pressures from governmental managers to accomplish work on a rapid time schedule, probably provides incentives for rising rather than for reducing costs. If a corporation is judged in terms of whether it accomplishes a result by a given deadline rather than by whether it accomplishes that result at a minimum cost, it will naturally pay less attention to costs and more attention to speed of accomplishment. On the other hand, where there is no given deadline, the cost-plus-fixed-fee contract may serve to prolong the work and induce the contractor to delay competition.[1]

In recognition of these disadvantages, the government has introduced cost controls over the years, to monitor contract performance and gain assurance that the contractor is properly managing the work. Examples of such controls include requiring the contractor to obtain government approval to incur overtime costs. Government approval is likewise required to subcontract work in excess of a specified dollar amount, or to make a product engineering change.[2] The most recent of these controls was Department of Defense Instruction No. 7000.2, entitled "Performance Measurement for Selected Acquisitions." This instruction was introduced in December 1967. It requires the contractor to adapt his internal

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[1] Bureau of the Budget, Report to the President on Government Contracting for Research and Development, (30 April 1962), p. 32

[2] ASPR 12-102.3(a) outlines the requirements for overtime and shift premium payments. ASPR 7-203.8 deals with subcontracts.

management control systems to provide data which (1) indicate work progress, (2) properly relate cost, schedule, and technical performance, (3) are valid, timely, and auditable, and (4) supply DOD managers with a practicable level of summarization. A copy of this instruction will be found in Appendix A.

Such controls are not without their own disadvantages, both for the contractor and the government. They require accountants, auditors, and contract administration personnel, which add another element of cost. With these additional personnel requirements, the CPFF contract tends to be more expensive to administer.[1] The controls are a reflection on the nature of the CPFF contract, in that there is a minimum incentive for the contractor to control costs. Controls of this nature would not be required on a firm-fixed-price contract and are specifically excluded by DOD Instruction 7000.2.

Nash holds the belief that the practice of instituting contract cost controls tends to insert government into contractors management to a great degree.[2] In addition, the contractor is subject to close scrutiny of all his contract costs and may incur expenses in justifying certain costs. If the contractor realizes that a cost overrun will occur, a series of discussions, explanations, and justifications may result. Nash advances an opinion aimed at this tendency of government:

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[1] Nash, Op. Cit., p. 110

[2] Ibid., p. 111

> The interference by government into contractor management is of questionable benefit . . . . This interference is beneficial to neither party and, in addition, is one of the causes of the failure of contractors to control costs on CPFF contracts.[1]

Apparently, this injection of control to scrutinize contractor performance has resulted from past abuses of the CPFF contract.

CPFF contracts are subject to further criticism on the premise that contract work may be commenced without a firm estimate of cost. As a result, the Department of Defense may be constrained in making valid program decisions, since firm cost estimates are lacking. This further tends to detract from the reliability of Defense budget estimates.

One additional disadvantage, to which the CPFF is prone, is called "buying in." In this situation, the contractor may bid an unrealistically low price in order to win the contract. A cost overrun would result in the contractor receiving the fixed fee, but a lower percentage of total cost. It may be argued that the contractor's return on investment is reduced thereby minimizing the buy-in tendency. Rudwick, however, believes that if the contractor is short of other work and cannot maintain production capacity, reduced return on investment would not be a sufficient deterrent.[2]

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[1] Ibid., p. 111

[2] Bernard H. Rudwick, Systems Analysis for Effective Planning, (New York: John H. Wiley & Sons, Inc., 1969), p. 422

Critical Aspects of Incentive Contracting

The primary purpose of establishing the incentive contracts was to improve contractor efficiency by lowering costs and raising the level of performance. The incentives offered are usually monetary in nature. They may be based on adherence to cost or price estimates, performance standards, or both.

Incentive contracting, in general, falls at a relative point between FFP and CPFF contracts. FFP and CPFF contracts are two polar cases. The incentive contracts are Fixed Price with Incentive Fee (FPIF) and Cost Plus Incentive Fee (CPIF). Both involve a target price or cost, target profit, and a sharing formula.

There are certain differences between FPIF and CPIF contracts. The FPIF contract usually sets a price ceiling expressed as a percentage of the target cost. The CPIF does not. CPIF contracts generally possess no requirement that the task be completed within the limits of the funds in the contract.[1] However, a maximum and minimum fee are specified.

The FPIF contract is the type most commonly employed in complete systems acquisition. Table 4 tends to support this assertion. For this reason, the discussion will be

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[1] Moore, Op. Cit., p. 221

directed to the FPIF contract. However, Fitzgerald believes that the disadvantages of FPIF are also common to CPIF contracts.[1]

Probably the most serious obstacle to effective incentive contracting is the difficulty in setting the initial target costs or prices. These contracts have been criticized for poor estimation of targets, particularly for setting the target price artificially high. If the target price is set higher than the expected price, the contractor is in a better position to remain within the target, and perhaps incur an underrun. The extra profits, based on the sharing formula, would appear to result from contractor efficiency, but would actually be due to an artificial estimate.

Past trends seem to indicate that costs of military items are not estimated with the same accuracy as their counterpart commercial items.[2] In this respect, the position of the Department of Defense is adverse to that of the contractor. The government's position is to negotiate a target price as close to expected levels as possible. On the other hand, actual costs may increase sharply during the work, and the contractor's strategy is to avoid serious cost overruns. The overrun could deplete profits in accordance with

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[1] U.S. Congress, Joint Economic Committee, _Military Budget and National Economic Priorities, Hearings_, before a Subcommittee on Economy in Government, 91st Congress, 1st Sess., 1969, pp. 785-794

[2] Moore, _Op. Cit._, p. 220

the terms of the sharing formula. The tendency is for the contractor to attempt to negotiate a target price that exceeds his expected costs. The gravity of this situation is stated by Moore as follows:

> To hand a contractor a large windfall profit that results from an exaggerated target cost is the antithesis of an incentive, and weakens the effectiveness of the sharing formula.[1]

Negotiations for the Mark II Avionics system for the F-111 with Autonetics, appear to exhibit both the tendency to exaggerate the initial estimate of cost, and also poor estimating of actual program costs. The original contract included a target price of $145.3 million. The price was based on a target cost of $132.2 million proposed by Autonetics, a profit of 10 percent, and a ceiling price of 120 percent of target cost. Autonetics' original estimate was for $183 million, but agreed to reduce this by $38 million in order to obtain the contract.[2]

It soon became apparent that Autonetics would be unable to meet even the contract ceiling price. In the period from September 1966, through March 1967, Autonetics made five new price estimates. Each was higher than the previous. By early 1968, it became apparent that the actual costs might reach $320 million. Though all the reasons for the cost

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[1] *Ibid.*, p. 220

[2] U.S. Congress, Joint Economic Committee, *Military Budget and National Economic Priorities, Hearings*, *Op. Cit.*, p. 799

overrun are unknown, a substantial portion has been attributed to design changes made by the contractor. At least $60 million was attributed to estimating error. The exact particulars of the estimating error are not specified.[1]

On one hand, Autonetics was accused of submitting an artificially high bid of $183 million. When design and performance problems arose, costs rose rapidly, and some estimating error was uncovered. When costs approached $320 million, Autonetics was accused of making a "buy-in" bid. This latter charge will be discussed in the following section.

Buy-In Bidding on Incentive Contracts.--The cost-plus-fixed-fee contract was previously criticized due to its susceptibility to a buy-in by contractors. The reason given was that there was little incentive to control costs and the contractor could make an unrealistically low bid. His fee would be affected only as a lower percentage of the expected costs. The incentive contracts were introduced with the intention, not only of controlling cost and improving performance, but of eliminating the buy-in bid. Introduction of a ceiling price, and decreasing profit pattern in the overrun situation, were intended to eliminate this tendency.

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[1] U.S. Congress, Joint Economic Committee, Military Budget and National Economic Priorities, Hearings, Op. Cit., p. 803

Experience with the C-5A and Mark II Avionics System seem to indicate that the incentive provisions of contracting are not eliminating the buy-in. Concerning the Mark II contract, Major General Murphy pointed out the apparent intentions of Autonetics in their bid submissions:

> It appears that the contractor knew very well what he was getting into but was so intent on winning the contract, that he was willing to buy in at a low price.[1]

The rationale advanced by General Murphy for the Autonetics bid are stated as follows:

> The contractor believed that he would not be held to the written agreements made at the time of source selection. . . . Autonetics adopted the strategy of reproposing without regard to the original contract, contending that the contract was not valid. The company failed to recognize, or did not believe, that the procurement system was shifting from oral promises to written agreements. . . . If it fails to enforce the contract, the Air Force and the Department of Defense can count on many more years of misleading promises from contractors and failures to meet contractual requirements.[2]

Mr. A. E. Fitzgerald, in testimony before the Proxmire Committee, contended that there was similar evidence of a buy-in by the Lockheed Aircraft Corporation in the C-5A contract.[3] Both contracts were Fixed-Price-Incentive-Fee.

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[1] Major General John R. Murphy, Director, Legislative Division, Department of the Air Force, in a letter to Senator William Proxmire (Washington, D.C.: June 20, 1969)

[2] Ibid.

[3] U.S. Congress, Joint Economic Committee, Op. Cit., pp. 595-615

In the light of this testimony, it appears that the buy-in tendency is present in the incentive contracts, as well as cost reimbursement types.

Uncertainties Affecting the Target Cost Estimate

To deal effectively with a target cost estimate, the degree of uncertainty must be considered. Probably the foremost uncertainty encountered in weapons system acquisition, is technological uncertainty. The degree of technological uncertainty tends to influence the accuracy of the cost estimate.

If a system to be procured incorporates components and design which have been utilized in previous systems, the degree of uncertainty tends to be reduced. The task of arriving at a reasonable cost estimate is less demanding. Previous experience could provide adequate data on which new systems costs could be based. Such is not always the case. Modern weapons systems are characterized by increasingly complex components and advanced performance requirements. Schultze states:

> The increase in complexity is driving the costs of systems to a point 10 to 20 times what they cost at the time of the Korean conflict.[1]

The point at issue is that considerable technological advancement is inherent with this increasing complexity.

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[1] Charles I. Schultze, in testimony before the Subcommittee on Economy in Government, Op. Cit., p. 65

There tends to be an insufficient prior data base on which to make cost estimates for future systems.

Another uncertainty affecting the original target cost is uncertainty in ultimate performance requirements. At the time development is commenced, the final system form may not be specifically defined. Changes may be introduced by dynamic tactical requirements, or brought about by achieving a new level in the state of the art. Once the system has been initially costed, any further changes will tend to bring on increasing prices.

In this situation, changes to the target cost initiated by the government, are usually subject to negotiation. Government responsible changes in the Mark II system were reported to be $20.2 million.

Optimism in Program Decisions

Getting a new weapons program going is not easy. As discussed, there are substantial risks and uncertainties. Realistic cost estimates tend to have a sobering effect on the Department of Defense hierarchy.[1] Perhaps, a realistic estimate of the cost of a proposal, may place it in an unattractive position before the Congress. For this reason, considerable optimism tends to pervade initial program decision making, both on the part of the contractor and

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[1] U.S. Congress, Joint Economic Committee, Op. Cit., p. 379

the Department of Defense. Scherer comments on this tendency as follows:

> Industrialists and military officers are inclined to view a programs future prospects through rose tinted glasses. There is a common belief that one should not rock the boat vigorously through criticism at the start of a program. The assumption is that troubles can be pin pointed and corrected later on when the program has its momentum. This attitude contributes significantly to the subsequent appearance of cost overruns, and it can lead to seriously defective decisions.[1]

Initial optimism has been evident in several past programs, notably the Skybolt and Nike-Hercules air defense missle system.

The contractor for the Skybolt program was the Douglas Aircraft Company. In 1958, Douglas competed for the Minuteman ICBM program, but lost the competition to Boeing. After this defeat, Douglas found its backlog situation desperate. Skybolt seemed to be the best opportunity, and it competed aggressively in the design competition. It abandoned its traditionally conservative engineering philosophy. It accepted extreme technical risks in order to promise maximum technical performance. It underestimated the difficulties of the Skybolt development tasks, submitting optimistic cost and delivery date estimations in the expectation that it would be bailed out a year or so later when the final contract provisions were estimated.[2]

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[1] Scherer, testimony before the Subcommittee on Economy in Government, Op. Cit., p. 379

[2] Ibid., p. 380

By 1962, the cost of the program, originally estimated at $890 million, had risen to $3 billion, and was still climbing.[1] The program was eventually cancelled.

The second case involved the Nike-Hercules air defense missle system. The prime contractor was Western Electric. Formal development began in 1953. At the time, the research and development team presented estimates of the costs to convert the existing Nike-Ajax units to use the Nike-Hercules. They said it could be done at $210,000 per battery through a field modification. However, two years later, during contract negotiations, they presented a new estimate. They then said that it would not be possible to make modifications in the field and instead should produce the equipment at the factory for $1.7 million per unit. Scherer comments on this case as follows:

> Western Electric officials admitted that their production engineering staff members knew early in the program that a field modification would prove to be impractical, but that they presented the highly optimistic cost estimates because they were more sellable to the Army and Congress.[2]

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[1] Ibid., p. 381

[2] Ibid., p. 381

CHAPTER III

A DISCUSSION OF COST ESTIMATING METHODS AND PROBLEMS

Criticisms leveled at the incentive contract series in the previous discussion cited "realistic target costs" as being a key contractor performance determinant. Had the target cost been set unrealistically high, any underruns resulting during contract performance might appear to be contractor efficiency, when in fact poor estimating technique could really be the reason. Similarly, in a cost overrun situation, a probable explanatory factor is bad estimation.[1] Robert N. Anthony, former Comptroller for the Department of Defense, stated the relationship of estimating to the quality of incentive contracting before the Subcommittee on Economy in Government:

> It (incentive contract) is a good contract, provided you can estimate the costs.[2]

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[1] Does not preclude the possibility of an intentional underestimate such as the "buy-in" bid. Peck and Scherer state: "Cost quotations were deliberately underestimated by contractors in order to sell the program to the services," in The Weapons Acquisition Process, (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1962), p. 19

[2] U.S. Congress, Joint Economic Committee, The Military Budget and National Economic Priorities, Hearings, before a Subcommittee on Economy in Government, 91st Congress, 1st Sess., 1969, p. 32

This comment provides an introduction for a discussion of cost estimating techniques, their problems, and their relation to cost overrun.

Definition and Perspective

A cost estimate, as used in this discussion, is a judgement or opinion, regarding the non-recurring cost of acquiring a weapon system; to include research, development, test, evaluation, production and procurement, but generally not the recurring costs of operation and maintenance.

In the acquisition of a system, such as the Mark II, estimates of cost are made at various stages in the process.[1] Breckner and Noah noted that estimation accuracy tends to increase as the system progresses in development. They attribute this tendency to experience gained in converting unknowns to knowns.[2] So as not to confuse experience refinements with early estimates, cost estimating, as used herein, shall refer primarily to the "initial systems cost estimate."

Cost Estimating Techniques

The techniques used for estimating systems costs range from intuition at one extreme, to a detailed application of

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[1] Autonetics made total cost revisions in June 1966, June 1967, and January 1968. These are itemized in detail in testimony before the Subcommittee on Economy in Government, U.S. Congress, Joint Economic Committee, Op. Cit., p. 804

[2] Norman V. Breckner and Joseph W. Noah, "Costing of Systems," in Defense Management, ed. by Stephen Enke, (Englewood Cliffs, N.J.: Prentiss-Hall, Inc., 1967), p. 57

labor and material cost standards at the other. The Air Force cost estimating manual lists five basic cost estimating methods. These are Industrial Engineering Standards; rates, factors and catalogue prices; estimating relationships; specific analogies; and expert opinion.[1] Other sources describe cost estimating methods as synthesis and analysis; round table estimating; estimating by comparison; detailed estimating; analytical appraisal; comparative analysis; statistical; and standards.[2]

This discussion shall not be all comprehensive but will limit the examination to three techniques; the Industrial Engineering approach, analogy, and the statistical approach.

Cost Estimating by Industrial Engineering Procedures

Estimating by Industrial Engineering procedures is broadly defined as an examination of separate segments of work at a low level of detail and a synthesis of the many detailed estimates into a total. At the lowest level of detail, the estimator begins with a set of drawings and specifies each engineering or production operation that will be required, the work stations where each operation will be performed, and the labor and material that will be required.

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[1] AFSC Manual 173-1

[2] J. P. Large, An Introduction to Equipment Cost Estimating, RM-5470-SA (The Rand Corporation, January 1968), p. 2

The detail required at the lowest level of estimation is illustrated in Table 5. Formation of a center bracket of steel plate is the example used. The name and number of the operations and the machine that will be used are given, along with estimates of the set-up time and operating labor cost. Standard set-up and operating costs are used in making the estimates whenever these exist. If standards have not been established, a detailed study is made to determine the most efficient method of performing each operation.[1]

The low level estimates are aggregated at each succeeding level, until a cost estimate for the entire system is attained. For example, the bracket in Table 5 could be a basic part of an airplane wing. The estimates for all the parts constituting that wing are assembled and totaled to estimate the cost of the wind. Likewise, the aggregated costs of the fuselage, landing gear, engines, and remaining subsystems are brought together and totaled. The result is the cost estimate for the aircraft. One of the largest aerospace firms figures that approximately 4500 estimates of this type are required to estimate the cost of an airframe using the Industrial Engineering approach.[2]

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[1] _Ibid._, p. 3

[2] Ibid., p. 5

TABLE 5

DETAILED LABOR COST ESTIMATE

Customer:	XYX Company	Part No.:	6789	Material:	1/8" x 5" C.R. Steel
Description:	Center Bracket	DRWG No.:	6613		Strip 20" Long

Dept.	Opera-tion	Operation and Machine		Setup Cost		Operating Labor		Overhead	
				Setup Hours	Cost	Output per Hr.	Cost/ 1000	Setup Labor	Oper. Labor
20	16241	Setup	Niagara 462	1/2	1.70				
20	16081	Shear	Niagara 462			3000	1.13		
20	16242	Setup	#4 Press	2/3	2.27				
20	11571	Perforate	#4 Press			1100	3.00		
20	16243	Setup	#4 Press	1	3.40				
20	12951	Form	#4 Press			450	7.26	12.90	9.98
18	14351	Tap	Tap Wheel			900	3.47		
18	16244	Setup	Plain Mill	1/2	1.70				
18	14661	Mill slots	Plain Mill			100	34.00		
18	15541	File burrs	Hand File			95	35.70	2.55	54.88
07	16245	Setup	Speed Lathe	1/4	.85				
07	11542	Burr & Mill	Speed Lathe			600	5.26		
07	16246	Setup	Mult. Drill	1/2	1.70	900	3.47		
07	11941	Ct. Sink 2H	Mult. Drill						
07	16247	Setup	Tap Machine	1/2	1.70				
07	16561	Tap 2 Holes	Tap Machine			400	6.88	5.31	9.76
19	15151	Dull Plate				1000	3.50		1.75
Quantity Required: 500				Totals	13.32		56.84	19.76	76.37

Source: Production Handbook, edited by L. P. Alford and John R. Bangs, (New York: The Ronald Press Co., 1953)

Cost Estimating by Analogy

Estimating by analogy derives the cost estimate by looking at experiences acquired in the production of a past system, and applying these experiences to the production of a future system, given certain likenesses and differences. For example, if System A required 100,000 direct labor hours, given the likenesses and differences in design and performance of proposed System B, the requirement for B might be estimated to be 125,000 hours. Starting in the 1950's, aircraft companies bidding on ballistic missle programs drew analogies between aircraft and missles to develop cost estimates for the missles. J. P. Large cites an example of drawing an analogy from aircraft production and extending this experience to a proposed missle system:

> Douglas Aircraft Company made a good cost estimate on the Thor intermediate range ballistic missle by comparing Thor with the Douglas DC-4 transport airplane.[1]

Douglas encountered a different situation at a later time when attempting to apply experiences gained in Thor construction to cost estimates of the Saturn S-IV stage. After adjusting for differences in size, the number of engines, higher performance and insulation problems, the cost estimate derived by analogy resulted in a cost overrun.[2]

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[1] Ibid., p. 5

[2] Ibid., p. 5

Statistical Techniques in Cost Estimation

In the statistical approach to cost estimating, explanatory variables such as weight, speed, power, frequency, and thrust, are used to develop estimating relationships. The estimating relationships in turn, are relied upon to predict costs of the system. Most estimating relationships are simple statements indicating that the cost of some system is directly proportional to the weight, area, volume, or some other physical characteristic of that system.

The emphasis is not on statistical theory or the computational aspects of statistics. Rather, some basic considerations are presented, which are involved in developing estimating relationships to be applied to equipment cost estimating.

Developing the Estimating Relationship and Regression Analysis.--An estimating relationship assumes that there is some direct relationship between cost and some other explanatory variable. The problem is to discover the appropriate relationship. This is done by first, deciding what variables are logically or theoretically related to cost, and then, by looking for patterns in the data that suggest a relationship between cost and these variables. Large indicates that weight is a widely used explanatory variable because of the generally held belief that as an

aircraft, ship or missle increases in weight, it becomes more costly.[1]

To illustrate this concept, assume that data were available on 10 previously produced aircraft. Figure 1 lists cost and weight data on 10 hypothetical aircraft. If this data were displayed graphically, it would immediately become evident that the data conform to a straight line. The apparent relationship between cost and weight in this example is a linear function. The equation of this line would be:

$$y = a+bx$$

The independent variable "y" (cost) is a function of some constant "a" ($2,500,000), plus the product of the aircraft weight (x), and the slope of the line (b).[2] The resulting line is a regression line of "y" on "x." An estimation of the value of a variable "y" (cost) can be obtained from a corresponding value of "x" (weight), from the regression line which fits the data.[3]

The estimating relationship is the regression equation obtained from the data. To apply this estimating relationship to the construction of a new aircraft, suppose the weight of

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[1] *Ibid.*, p. 33

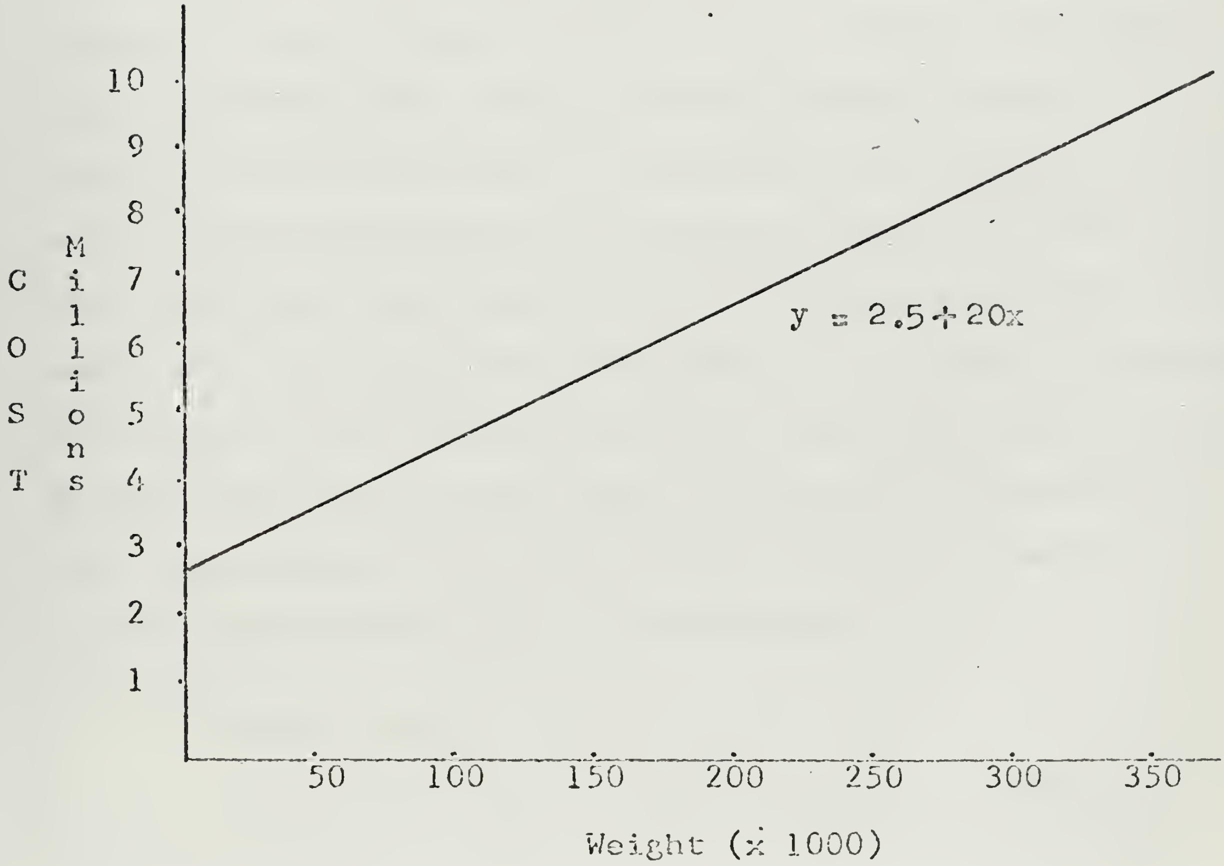
[2] Mathematical derivation of a linear function is presented by John E. Freund, *College Mathematics with Business Applications*, (Englewood Cliffs, N.J.: Prentiss-Hall, Inc., 1969) pp. 91-95

[3] Murray R. Spiegel, *Theory and Problems of Statistics*, (New York: McGraw-Hill Book Co., 1961), p. 221

FIGURE 1

COST-WEIGHT DATA OF 10 HYPOTHETICAL AIRCRAFT

AIRCRAFT	COST (Millions)	WEIGHT (x 1000)
A-1	3500	50
A-2	4000	75
A-3	4500	100
A-4	5500	150
A-5	6000	175
A-6	6700	210
A-7	7500	250
A-8	8300	290
A-9	9000	325
A-10	9500	350



the proposed aircraft is to be 300,000 pounds. Utilizing the estimating equation:

$$\text{Cost} = 2{,}500{,}000 + 20\ (300{,}000)$$
$$= 8{,}500{,}000.$$

Assuming that the cost to weight relationship is valid, the cost estimator might state that the cost of a 300,000 pound aircraft would be approximately $8.5 million, based on prior experience.

In actual practice, the values of aircraft cost to weight would not usually correspond exactly to a straight line when graphed. Exact correspondence would be extremely rare.[1] To derive a useful relationship in that case, the estimator could attempt to approximate a linear regression line by applying the method of least squares to fit a straight line to the data.[2] The problem is to derive estimates of the parameters of "a" (constant) and "b" (slope of the regression line), such that the regression equation will approximate the sample data as closely as possible. The values of "a" and "b" are determined by the requirement that the sum of the square of the deviations of the sample observations from the regression line will be at a minimum. The two normal equations for linear regression are:

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[1] Large, Op. Cit., p. 36

[2] Computational techniques of the Least Squares method is treated by John E. Freund, Elementary Business Statistics, (Englewood Cliffs, N.J.: Prentiss-Hall, Inc. 1964) pp. 304-307

$$\sum y = na + b\sum x$$

$$\sum yx = a\sum x + b\sum x^2$$

In this example:

y = cost of the aircraft

x = weight of the aircraft

n = number of observations in the sample

$\sum$ = sum of

Substituting the appropriate values of x, y, and n into the normal regression equations, and solving simultaneously, yields the linear equation of the form $y = a + bx$ for the regression line of best fit to the aircraft data.

The usefulness of cost prediction of a regression line depends on the extent of the dispersion of observed values about the line. The greater the dispersion of observed values of y about the regression line, the less accurate estimates based on the line are likely to be.[1]

Higher techniques of regression analysis.-- An examination of graphically portrayed data of cost and weight might indicate that a linear relationship is appropriate. However, it cannot be concluded definitely that some type of non-linear relationship might not be preferable. One form frequently used is logarithmic regression. The basic equation is:

$$y = ax^b$$

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[1] Large, Op. Cit., p. 41

The variables of the equation are transformed logarithmicly. The resulting equation is linear in the logarithms of the variables:

$$\text{Log } y = \log a + b\ (\log x)$$[1]

The first step is to take the original data for x and y contained in Figure 1, and convert these data to logarithms. The next step is a simple linear regression analysis of the data in logarithmic form.

A third form of regression analysis considers the effect on cost of more than one variable. This technique is known as Multiple Regression Analysis. An example of this technique would be analysis of the effect on cost of both weight and speed, or weight and thrust.[2] The equation of multiple regression is of the form:

$$z = a + bx + cy$$

Problems with Cost Estimating Methods

Industrial Engineering Procedures

Cost estimating by Industrial Engineering procedures requires numerous detailed estimates starting at a low level of detail. It was previously cited that approximately 4500 estimates were required to estimate the cost of a typical

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[1] *Ibid.*, pp. 50-53

[2] The computational aspects of multiple regression analysis are relatively involved. For treatment of computation as well as a mathematical derivation of the equation, the reader is referred to J. P. Large, *An Introduction to Equipment Cost Estimating*, RM-5470-SA (The Rand Corporation, January 1968), pp. 60-65

airframe. For that reason, Industrial Engineering estimates are time consuming and costly. They require more personnel and data than are likely to be available to government estimators.[1]

Industrial Engineering estimates have been found to be less accurate than statistical estimates in many cases. Large states that the reason for this is:

> That the whole generally turns out to be greater than the sum of the parts.[2]

Because of this reason, and for cost, time and personnel considerations, aircraft manufacturers and government estimators tend to avoid using the industrial engineering approach.[3]

Industrial Engineering estimators must also work with the uncertainties that are common in aircraft production, technological uncertainty being the foremost. As systems become increasingly complex, the difficulty lies in specifically defining the character of the proposed system. To make a reliable estimate of manufacturing costs, the estimator must know all the elements that go into them.[4] Experience has indicated that changes or modifications are made to system specifications at different stages of development and

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[1] Ibid., p. 2 [2] Ibid., p. 5 [3] Ibid., p. 6

[4] Thomas F. McNeill and Donald S. Clark, Cost Estimating and Contract Price, (New York: American Elsevier Publishing Company Inc., 1966), p. 154

production. For example, Autonetics made significant changes to its designs of the Mark II Avionics system after initial cost estimates had been made. These changes were made while development was going on in parallel in order to meet the original performance specifications.[1]

It is clear that changes of this nature could have a considerable impact on initial cost estimates. The Industrial Engineering estimator, working from sketches, blueprints, or word descriptions of some item that has not been completely designed is at a disadvantage. He can assign costs only to that work he knows about in advance. Even assuming that no design changes were made through the first production run of a particular aircraft, experience shows a tendency for production runs of like models to be of limited length and characterized by numerous design changes. Production rates have tended to vary frequently and unexpectedly, with the subsequent introduction of new or changed components. Large notes that:

> The proportion of new components introduced during a production cycle is probably higher in the airframe industry than in any other.[2]

These changes cannot be known to the estimator in advance, thus the tendency to introduce error into the initial cost estimates.

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[1] U.S. Congress, Joint Economic Committee, The Military Budget and National Economic Priorities, Hearings, before the Subcommittee on Economy in Government, 91st Congress, 1st Sess., pp. 800-801

[2] Large, Op. Cit., p. 6

Analogy

The major drawback to cost estimating by analogy is stated by Large:

> Estimating by Analogy is essentially an intuitive process, and as a consequence requires considerable experience and judgement to be done successfully. Statistical procedures are preferable in most situations.[1]

In spite of this drawback, Large explains that it may be necessary to resort to the method of Analogy in some circumstances because the available data do not provide a systematic basis for estimating cost behavior.[2] The Douglas Aircraft Company based missle cost estimates on aircraft production experience, as previously cited. A great change in technological requirements in that case left relatively little experience data on which to base a cost estimate.

Statistical Techniques

An estimating relationship can only be derived from information on what has occurred in the past. The past is not always a reliable guide as to what will occur in the future. Thus, statistical estimating is subject to uncertainties which also tended to be drawbacks to Industrial Engineering or Analogy estimating techniques.

The uncertainties to which statistical estimating is prone, stem from two sources:

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[1] Ibid., p. 7

[2] Ibid., p. 7

(1) The uncertainty inherent in any application of statistics.

(2) The uncertainty that an estimating relationship is applicable to a particular system.

Concerning the first source of statistical uncertainty, little need be said, other than a word of caution stated by Freund:

> So far as forecasting and estimating from statistical data is concerned, it must be remembered that any projection of past experience to the uncertain future is speculative and hazardous.[1]

On the second source of uncertainty, whether or not the estimating relationship is applicable to a particular system, the question of the reliability of the predicting equation is raised. Contrary to what the regression equation may indicate, cost and the explanatory variable may not be related in the same manner. A particular sample could show such a relationship out of pure chance when in fact none exists. Further, the regression equation is only one of a large number that could be obtained from different samples from within the same population. In other words, the predicted cost, may not be the true cost.[2]

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[1] John E. Freund, Elementary Business Statistics, (Englewood Cliffs, N.J.: Prentiss-Hall, Inc., 1964), p. 347

[2] Methods of evaluating the reliability of certain data within established or theoretical limits exists. Examples of such techniques include the theories of probability and correlation. It is not within the scope of this paper to elaborate upon these techniques. Theoretical presentations of this material are made by W. A. Spurr and C. P. Bonini,

The Relationship of Cost Estimating Uncertainties to Cost Overrun

From a discussion of cost estimating by Industrial Engineering Techniques, Analogy, or statistics, one thing is evident. Whatever problems may be inherent to each method, they all share uncertainty as a factor which lessons their effectiveness. The question is: To what degree does uncertainty in cost estimation influence the final cost of the system? Experience during the 1950's showed that there was often a large difference between original estimates and the final costs of a number of weapons systems. The Department of Defense began looking at case histories of major weapons systems in an attempt to identify the reasons for the discrepancies. In particular, the Department wanted to know if the reasons for the cost overruns were bad estimating, or some other factor.

Table 6 lists 16 aircraft and 6 missles developed prior to 1958 along with the ratio of actual cost to initial estimate. The ratio is shown as the factor increase. The main point of interest is the reason for these increases and, specifically, if they are due to bad estimating. A study of the development histories of the equipment shown

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Statistical Analysis for Business Decisions, (Homewood, Ill.: R. D. Irwin, Inc., 1967) and John E. Freund, Elementary Business Statistics, (Englewood Cliffs, N.J.: Prentiss-Hall, Inc., 1964)

TABLE 6

FACTOR INCREASES OF THE PRODUCTION COSTS OF EQUIPMENT

Equipment	Factor Increase
Fighter	3.9
Fighter	2.6
Fighter	2.0
Fighter	1.5
Fighter	1.7
Fighter	1.2
Fighter	1.0
Fighter	1.0
Fighter	1.1
Bomber	6.2
Bomber	2.8
Bomber	1.1
Cargo	1.4
Cargo	1.5
Cargo	1.0
Cargo	1.0
Missle	14.7
Missle	9.4
Missle	4.4
Missle	8.2
Missle	1.5
Missle	1.1

Source: A. W. Marshall and W. H. Meckling, _Predictability of the Costs, Time and Success of Development_, P-1821 (Santa Monica: The Rand Corporation, December 1959)

in Table 5 was made in an attempt to answer this question. The study led to the following conclusions:

> When early estimates are made of what it will cost to produce or develop something new, the estimator typically bases his estimate on the current design and the currently planned program for development. If he is estimating cost of production, he gets a total cost by costing the various components as presently conceived and aggregating those. If he is estimating the cost of development, he estimates the cost of test articles, engineering man-hours, etc., as presently planned and aggregates those. He does not specify what performance he is associating with the particular design nor does he indicate the date at which this performance is to be operationally available. He is simply costing a physical configuration and/or the physical resources contemplated in the current development plan.
>
> As development proceeds, however, these initial designs and plans are almost invariably changed, either because of unforeseen technical difficulties that forestall meeting performance requirements, or because the customer decides it is essential that the equipment be modified so as to keep pace with changing predictions of enemy capabilities, new operational concepts, and new technological possibilities.
>
> . . . In principle it would be possible to factor into two parts the total error in cost estimates as they are prepared: (1) the part due to errors in the costing of the configuration supplied to the cost estimator (i.e., the intrinsic error in cost estimating) and (2) the part due to changes in the configuration as development progresses. In practice, it has not been possible to carry out this separation. However, it is our belief that the intrinsic errors in costing a fixed configuration tend to be small relative to the other source of error in the costing of most major items of military equipment.[1]

In other words, of the two types of error listed above, requirements uncertainty is generally held to be

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[1] A. W. Marshall and W. H. Meckling, Predictability of the Costs, Time, and Success of Development, P-1821 (Santa Monica: The Rand Corporation, December 1959)

responsible for the major portion of the factor increases. In order to minimize requirements uncertainty, the Department of Defense has introduced the Contract Definition Phase (CDP) for major defense contracts. A rigorous definition of requirements prior to contractor selection is intended to reduce this type of uncertainty in the future.[1]

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[1] Large, Op. Cit., p. 85

CHAPTER IV

AN EXAMINATION OF ECONOMIC TRENDS AND THEIR RELATIONSHIPS TO COST OVERRUN

In a rebuttal to Congressional criticism of C-5A cost overruns, Lockheed Aircraft's president, A. C. Kotchian, cited economic inflation as the major cause.[1] He did not state the specific percentage factor of the total overrun that was attributable to inflation. More recently, the amount of overrun on the C-5A program attributable to inflation has been stated to be approximately $627 million.[2] At that time, the total overrun was estimated to be approximately $1.3 billion. If the $627 million estimate were correct, inflation would be responsible for 48 percent of the overrun.

On the other hand, Scherer classifies inflation as a minor factor, in the C-5A case. In prepared testimony for the Subcommittee on Economy in Government, he stated:

> Economy-wide inflation has been a contributing factor (to cost overrun) in the last few years, although it is a little hard to take seriously, claims that much of the C-5A's 64 percent (of target price overrun is attributable to this cause

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[1] "The Inflated Case of the C-5A," Armed Forces Management, July, 1969, p. 71

[2] Harold B. Meyers, "For Lockheed, Everything's Coming Up Unk-Unks," Fortune Magazine, August 1, 1969, p. 77

> when the wholesale price index for metals and metal products rose by only 11 percent between 1960 and 1968.[1]

With the C-5A, as well as with other systems acquired in the past, there is a considerable difference of opinion concerning the contribution of inflation to cost overrun.

It appears to be somewhat difficult to specifically isolate the exact amount of inflation induced cost overrun. This seems to be particularly true with large systems acquisition where the total price may exceed $1 billion. Specifications changes and uncertainties tend to lead to higher costs and further tend to obscure the portion of overrun which may be due to economic reasons. For that reason, this discussion will examine economic trends, rather than seek an exact overrun inflationary factor. To complete this task, a presentation of U.S. economic trends is made, followed by an examination of some specific indicators which may show a relation to cost overrun. Finally, an examination of some recent overrun cases, in an attempt to determine intuitively if the amount of overrun has conformed to the economic growth trend.

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[1] U.S. Congress, Joint Economic Committee, The Military Budget and National Economic Priorities, Hearings, before a Subcommittee on Economy in Government, 91st Congress, 1st Sess., 1969, pp. 379-383

United States Economic Trends (1958-1969)

Beginning in 1958, the United States enjoyed both price stability and an expanding economy. Until 1965, prices had been essentially unchanged. Labor costs had barely moved, as gains in productivity had largely offset moderate increases in hourly labor costs.[1] The economic expansion continued through 1965 without the presence of significant inflation. By December of 1965, the unemployment rate had decreased to 4.1 percent. This rate was just slightly higher than the 4 percent interim goal set by the Kennedy Administration in 1962.[2] The U.S. economy had practically achieved full employment. Full employment was finally reached in 1966, with a 13 year low unemployment rate of 3.9 percent.[3]

In 1964 and 1965, expansionary tax policies had stimulated the economy and brought a strong increase in total demand. Added to this was additional Vietnam expenditures which made their first impact on the economy in 1966, marking

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[1] Economic Report of the President, together with the Annual Report of the Council of Economic Advisors, January 1966, (Washington, D.C.: Government Printing Office, 1966), p. 37

[2] *Ibid.*, p. 31

[3] Economic Report of the President, together with the Annual Report of the Council of Economic Advisors, January 1967 (Washington, D.C.: Government Printing Office, 1967) p. 37

turning point in real economic growth. These factors brought a shift away from price stability.[1] The price increases were due in large measure to the acceleration in the growth of demand which began in mid-1965, and to the particularly rapid increase in output of capital goods and defense products. Demand had been rising since 1961, but that had been during a period when there was an abundant supply of labor and unused equipment.[2]

The sharp rise in demand for defense products and capital goods imposed special pressures on the metals and machinery industries. In some branches of these industries, the limits of efficient utilization were surpassed. In a few, output was close to the absolute limitations on capacity.[3]

There were also imbalances in the labor markets which created increasing difficulties as unemployment declined. Workers in low paid occupations could not be without substantial upward adjustments in wage scales. Wages began to rise faster at a time when productivity began to slow down.[4]

President Johnson summarized the reasons for the upward pressure on prices in his Economic Report:

> Price rises can be traced to imbalances created by the special pressures of Vietnam procurement and booming private investment. The spurt of demand . . . simply

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[1] *Ibid.*, p. 29

[2] *Ibid.*, p. 73

[3] *Ibid.*, p. 73

[4] *Ibid.*, p. 74

> exceeded the speed limits of the Economy's ability to adjust. Some price advance was the inevitable cost of the adjustments required in recovering from a decade of slack. Wages had to be raised sharply in underpaid occupations which previously held their labor only because the alternative was no job at all. Producers in once stagnant, low profit industries, saw opportunities for expansion and found it possible to raise prices and earnings in order to attract needed capital. Demand pressed harder on skilled occupations and professional services where we had trained too few persons to meet the needs of a high employment economy. Some price increases would have still occurred had we moved at a steadier pace. But these price increases could have come slowly enough and have been small enough not to threaten a chain reaction of wages chasing other wages - wages chasing prices - prices chasing wages - and prices chasing other prices.[1]

This period marked the end of real growth and overall economic stability. President Nixon, in a backward look at this period, commented:

> "Inflation was in full tide."[2]

Through 1967 and 1968, inflation continued unabated. By the first half of 1969, the rate of price increase reached 5.2 percent, the largest rate of growth since the Korean War.[3] In the second half of 1969, the rate of increase had subsided to 4.7 percent. This shift in the rate of price increase signalled a possible downturn in the economy. The slowdown was most likely in response to contractionary fiscal and monetary policies applied commencing in 1967.[4]

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[1] Ibid., pp. 5-6

[2] Economic Report of the President, together with the Annual Report of the Council of Economic Advisors, February 1970, (Washington, D.C.: Government Printing Office, 1970), p. 6

[3] Ibid., p. 29

[4] Ibid., p. 30

Specific Economic Indicators (1958-1969)

In examining some specific economic trends, particular attention is given to labor, wholesale and consumer prices. 1958 is used as the base year.

Labor prices remained at a fairly stable rate of growth from 1958 through 1965. During that period, the average annual hourly increase was 6.5 cents. By the end of 1965, an accelerated upward trend became apparent. In 1969, hourly earnings were increasing at a rate of 27.0 cents annually. Average wages ranged from $2.11 in 1958 to $3.28 in 1969. Figure 2 lists the average prevailing hourly wage in the manufacturing industry by year, and graphically illustrates the accelerating growth rate from 1965 through 1969.

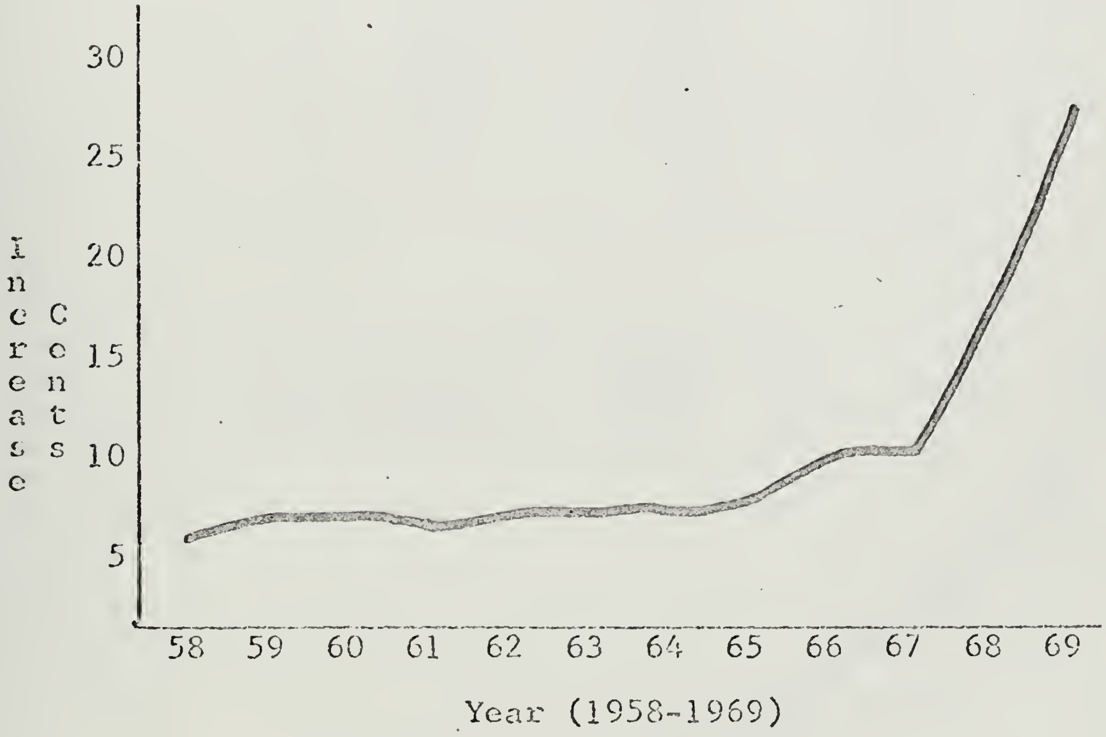
The wholesale price index followed approximately the same trend as labor from 1958 to 1964. That is, there was a stable trend through that period. After that, there was a rapidly increasing upward tendency through 1969. There appears to be slight differences in the behavior of prices for machinery and those for metal and metal products. The price index for metal and metal products began a rapid growth rate in 1963, two years earlier than the general accelerating growth rate for machinery. Figure 3 lists the wholesale

FIGURE 2

AVERAGE HOURLY EARNINGS IN MANUFACTURING INDUSTRIES (1968-1969)

Year	Wage	Year	Wage	Year	Wage
1958	2.11	1962	2.39	1966	2.72
1959	2.19	1963	2.46	1967	2.83
2960	2.26	1964	2.53	1968	3.01
1961	2.32	1965	2.61	1969	3.28

Rate of Increase in Manufacturing Wages



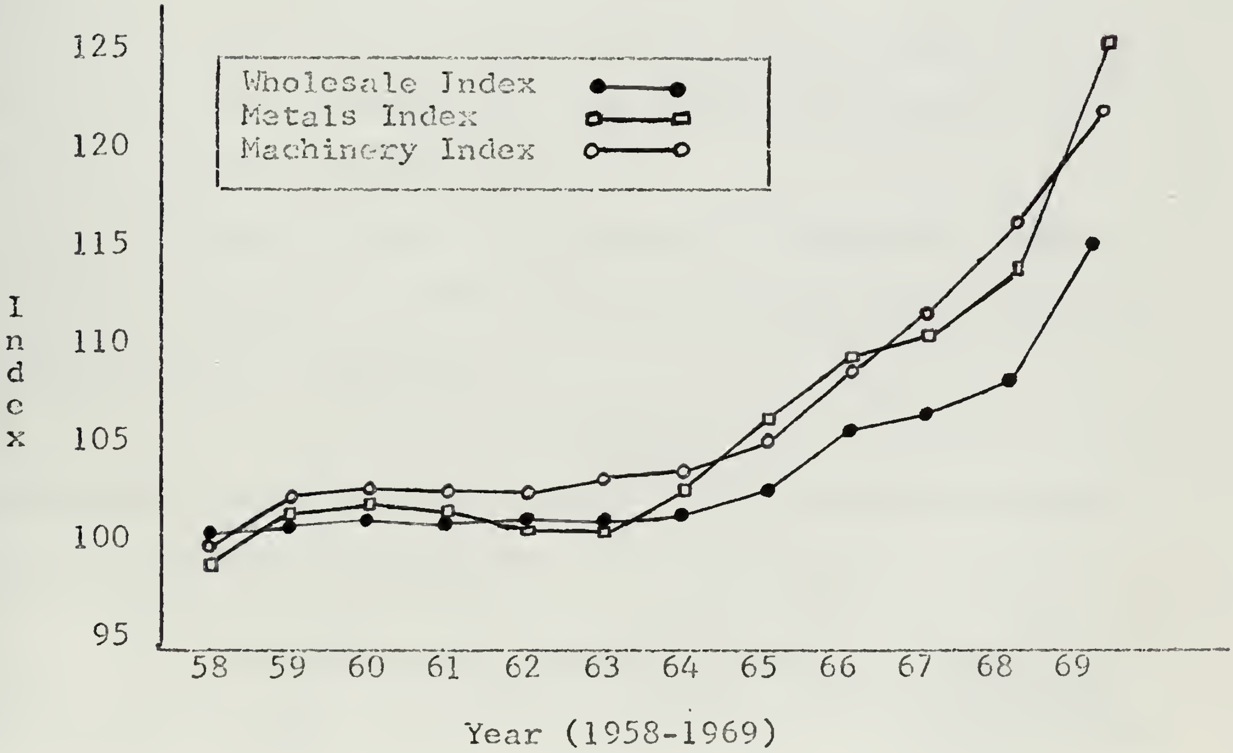
Average Hourly Earnings

Source: Adapted from the Statistical Abstract of the United States, 1969 (Washington, D.C.: Government Printing Office, 1969)

FIGURE 3

WHOLESALE PRICE INDEX (1958-1969)

Year	All	Metal & Metal Products	Machinery
1958	100.4	99.1	100.0
1959	100.6	101.2	102.0
1960	100.7	101.3	102.9
1961	100.3	100.7	102.9
1962	100.6	100.0	102.9
1963	100.3	100.1	103.1
1964	100.5	102.8	103.8
1965	102.5	105.7	105.0
1966	105.9	108.3	108.2
1967	106.1	109.6	111.8
1968	108.7	112.4	115.2
1969	115.1	123.8	121.9



Source: Adapted from the Statistical Abstract of the United States, 1969 (Washington: Government Printing Office, 1969)

price index for 1958 through 1969. Additionally, the indexes for metals and machinery are comparatively displayed. The trends are illustrated graphically.

The consumer price index for the same period is listed and illustrated graphically in Figure 4. The accelerating growth in prices between 1965 and 1969 is obvious.

Two significant features of the price data contained in Figures 2, 3, and 4 relate to the time frame. For purposes of analysis, the periods 1958 through 1965, and from 1965 thereafter, are of particular interest. Consumer, wholesale, and labor prices during the first period increased at almost a constant rate. Price as a function of time could be approximated by a relation of the form:

$$y = a + bx$$

While it is true that the data do not exactly match the function, the least squares line of best fit would result in a very small amount of dispersion.[1]

The period after 1965 presents a different trend. Price as a function of time during that period could best be described by the equation:

$$y = ab^x$$

An empirical examination of Figures 2, 3, and 4 would tend to verify these relationships.

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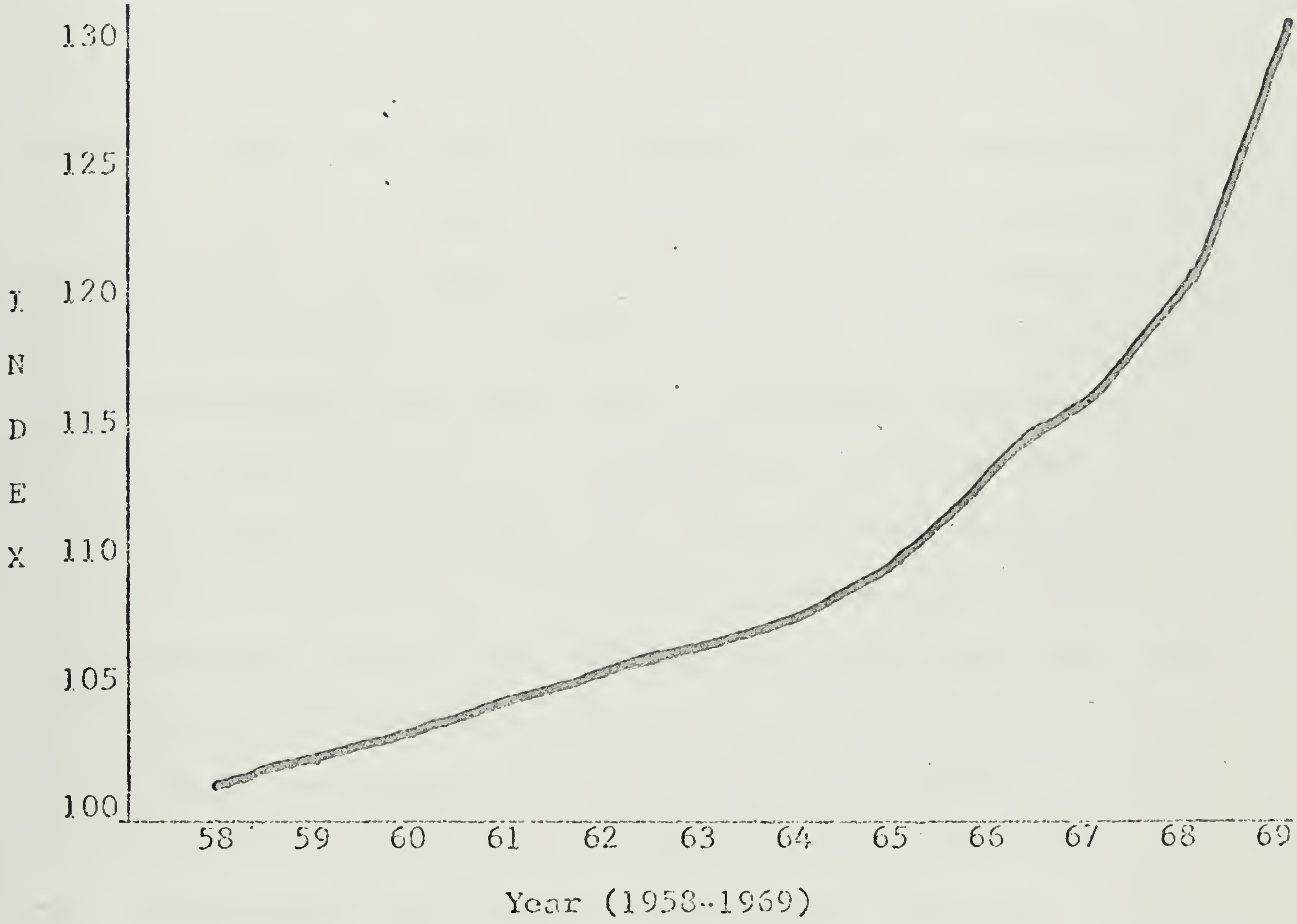
[1] The computational aspects of fitting data with a least squares line is covered by John E. Freund, Elementary Business Statistics, (Englewood Cliffs, N.J.: Prentiss-Hall, Inc., 1964), p. 304

FIGURE 4

CONSUMER PRICE INDEX (1958-1969)

Year	Index	Year	Index
1958	100.7	1964	108.1
1959	101.5	1965	109.9
1960	103.1	1966	113.1
1961	104.2	1967	116.3
1962	105.4	1968	121.2
1963	106.7	1969	131.3



Source: Adapted from the Statistical Abstract of the United States, 1969 (Washington: Government Printing Office, 1969)

The linear and exponential economic trends just described would suggest some effect on contract price outcomes. Contracts negotiated prior to 1965 and completed subsequent to 1966 might tend to be affected to the greatest degree. The rationale for this tendency is set forth in the following paragraph.

Contracts for weapons systems procurement normally take into account the length of time involved to complete the task. Further, allowances are made for increases in the prices of labor and materials based on the best estimates of economic trends.[1] Projections based on economic performance prior to 1965 would appear to offer no particular trouble provided that this trend remained in effect. For projections made for periods after 1965, based on previous experience, a cost overrun factor due to inflationary pressures seems to be involved. For example, the average price of labor in manufacturing industries increased approximately 2 percent per year from 1958 to 1965. Assume that a contract negotiated in January 1964 included labor expected to cost $1 million in 1964 prices. Further assume, that the task required by the terms of the contract will be completed in December 1969 with labor effort to be divided evenly over the period of the

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[1] U.S. Congress, Joint Economic Committee, Military Budget and National Economic Priorities, Hearings, Op. Cit., p. 609

contract.[1] The final assumption is that the economy will continue in a stable fashion, and that the cost of labor should increase at a rate of approximately 2 percent annually.

Based on these assumptions, the projected labor costs should approximate $1,087,879 for the term of the contract. If the contract target price allowed for this projected cost growth, the final cost should approximate the target price. No cost overrun is involved, even though costs are rising. Should labor price not follow a stable trend, as shown in Figure 2, the cost of labor in this contract would amount to approximately $1,114,253. Instead of a stable 2 percent labor cost increase per year, the actual increase for 1966 through 1969, was 4, 5, 7, and 9 percent respectively. The difference in cost is $62,901. This difference is the portion of cost overrun due to abnormal economic escalation, or inflation. It is noted that the overrun amounts to approximately 5.9 percent of the labor target price, over the entire contract period. Table 7 compares these two rates of price increase over the contract period.

Application of this example to metal and material price changes would yield similar trends. The actual

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[1] This assumption is made for illustrative purposes only. In practice, labor intensity would tend to vary considerably over the contract period depending on the stage of the contract, (i.e., R&D, Production, etc.).

TABLE 7

EFFECT OF INFLATION ON A HYPOTHETICAL CONTRACT

	Projected Data		Actual Data	
Year	Rate of Change %	Cost of Labor	Rate of Change %	Cost of Labor
1964	2	$ 166,666	2	$ 166,666
1965	2	170,000	2	170,000
1966	2	173,400	4	176,800
1967	2	176,868	5	185,640
1968	2	180,405	7	198,635
1969	2	184,013	9	216,512
	Total	$ 1,051,352		$ 1,114,253

Actual Labor Cost	$ 1,114,253
Projected Cost	1,051,352
Cost Overrun	$ 62,901
Cost overrun as a percent of target labor price	5.9

wholesale price index, however ranged from 100.4 in 1958 to 115.1 in 1969. This suggests that the percentage of overrun due to inflation would tend to be smaller for materials than labor. The rate of increase was not as great.

The foregoing example assumed a well defined product with no change during the contract period. With complex weapons systems, numerous changes and uncertainties add to the difficulty in isolating the exact factor of overrun due to abnormal economic trends. Nevertheless, the factor would appear to be somewhat smaller than stated by the Lockheed Corporation. Scherer conceded that simple economic inflation was surely a contributing factor to cost overrun, but that it was a relatively minor matter.[1]

Influence of Inflation on Recent Systems Procurement

The following section is devoted to an examination of some recent systems acquisitions. Each involve a substantial cost overrun. The causes of the overrun have been roughly approximated in each case.

Mark II Avionics System for F-111

Estimates of the cost of the Mark II system have reflected a steady and substantial rate of increase since Autonetics was selected as the contractor in June 1966. The following figures indicate the size of this increase:

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[1] U.S. Congress, Joint Economic Committee, "Military Budget and National Economic Priorities," Op. Cit., p. 379

(Mark II Dollar Amounts in Millions)

Date of Estimate	R.D.T.&E.	Production	Total Program
June 1966	$ 100	$ 500	$ 600
December 1966	190	600	790
June 1967	290	820	1,110
January 1968	330	1,180	1,510

These estimates were prepared by the contractor.[1]

The cost overruns in this case were attributed to numerous design changes made by Autonetics and the Government. It is significant that inflation was not considered a major factor, even though these substantial increases took place in a period of sharply rising prices. Further, Autonetics claimed that price increases could not be identified with any specific change. In its Cost Traceability Report, submitted on October 2, 1967, Autonetics stated that:

> Because of the complex interrelationships of the activities and changes during the period June 1966 to April 1967, it is not possible to estimate the cost effect of each individual change.[2]

An Air Force Cost Trace Team, in April 1968, analyzed the Mark II cost increases. Government changes in design were claimed to be responsible for $20.2 million. The remainder was deemed caused by contractor design changes, and poor in-house cost control. Although materials and labor price increases were contributing factors in part, they were not considered major items.[3]

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[1] *Ibid.*, p. 803

[2] *Ibid.*, p. 802

[3] *Ibid.*, p. 803

Lockheed C-5A Transport

As stated previously, the procurement of Lockheed's C-5A transport has been subjected to apparently large overruns. The base price was stated to be $3.4 billion, with the ultimate price reaching approximately $5.4 billion. This figure is the subject of some dispute in recent months. Not only is the amount of overrun questioned, but the factors constituting the overrun appear to be in doubt. The following estimates were made in November 1968, by the Department of the Air Force, Mr. A.E. Fitzgerald, and Assistant Secretary Charles:[1]

C-5A	Fitzgerald		Air Force		Charles	
	1965	1968	1965	1968	1965	1968
R.D.T.&E. plus production (in billions)	3.4	5.3	3.1	4.3	. . .	5.1

The estimates of overrun due to inflation also varied considerably. Meyers attributed $627 million to inflation.[2] The Air Force and Fitzgerald cite $500 million and $204 million respectively, as the inflationary portion of the overrun.[3] Senator Proxmire considers inflation to be less significant than alleged, and has stated:

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[1] Ibid., p. 311

[2] Meyers, Op. Cit., p. 77

[3] U.S. Congress, Joint Economic Committee, "Military Budget and National Economic Priorities, Hearings," Op. Cit., p. 609

> According to the Air Force, the cost growth in the C-5A program has resulted from normal development problems and inflation. The inflation argument, which is supposed to account for $500 million of the cost growth, appears questionable. The contract contains a provision to protect the contractor from unforeseeable price changes in the economy . . . . If future inflation for at least three years was included in the price, it is hard to see why inflation should be a major factor in later increasing the price.[1]

The preceding testimony seems to suggest that inflation might not be as large a factor in a cost overrun situation as is commonly supposed. At any rate, the range of estimates is large enough to suggest that the inflationary factor in a cost overrun cannot be precisely identified.

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[1] U.S. Congress, Senate, Senator Proxmire speaking on Senate Bill S-2546, 91st Congress, 1st Sess., September 4, 1969, Congressional Record, S9980.

CHAPTER V

CONCLUSIONS

The Factors of Cost Overrun

The examination of Government contracting methods, cost estimating tools, and economic events, tends to support the assertion that factors leading to cost overrun pervade the weapons acquisition process. Apparent overrun factors emerged in the discussion of each broad area. In some cases, the factors appeared to be interrelated with tendencies dependent on two or more of the areas discussed. However, in most instances, the problem revolves around uncertainty or optimism. This discussion will recapitulate the broad sections previously examined, and draw out the factors that seem to result in the overrun problem.

Overrun Factors in Government Contracting

In contracting, two factors appear to stand out as being the chief contributors to cost overrun. These are the tendency for contractors to attempt to "buy-in" on a program, and technological uncertainty.

The buy-in tendencies were evidently recognized prior to the 1960's, particularly with the use of CPFF contracts. Substitution of a larger percentage of incentive contracts and firm-fixed price contracts apparently failed to stop this practice. The Fitzgerald and Murphy testimony seem to indicate that sufficient evidence is available to show that the practice was used by Autonetics and Lockheed. Similarly, it may be a reasonable assumption to state that it was used in some of the systems studied by Marshall and Meckling. Likewise, other systems would not tend to be immune from contractor buy-in. It was Congressional concern that caused the apparent buy-in to be recognized, in the case of the C-5A and Mark II. If the buy-in commonly exists, it may go unnoticed in numerous other systems acquisitions.

Technological uncertainty has been an overrun factor in the past. From the evidence, it appears that difficulty will be encountered in the future with systems acquisition. As an overrun factor, technological uncertainty could be classified as one which might never be adequately quantified. That is to say, its existence is recognized and somewhat taken for granted, but it is likely to remain the greatest difficulty to realistic target establishment. In air systems procurement, the degree of departure from designs used in past systems tend to result in greatest dispersion of costs

estimates from the true cost. Provided that past performance data can be utilized in new systems, the experience could result in a narrower and more accurate speculation on the final cost. As Schultze pointed out: increased complexity, generally yields increased uncertainty. The uncertainty in turn, tends to drive costs to a point many times what was experienced in the past. With technology advancing constantly, it might be inferred that margins of error could become larger. At this point, however, evidence does not support that contention, since cost experience on major systems has been largely erratic.

The Marshall and Meckling studies seem to point out one trend. Overrun factors in general were larger in more complex systems, such as fighters and missles. They tended to become smaller in less sophisticated aircraft, such as transports. This trend appears to indicate a higher overrun with greater complexity. There is however, no definite relationship that can be stated from the evidence, that can be quantified.

A conclusion can be drawn from the relation of technological uncertainty to cost outcome. Uncertainty seems to cause initial cost estimates to vary the greatest degree from final cost. As system development progresses, the degree of error should become smaller, approaching zero

as the system approaches completion. It does not appear that the technological portion of uncertainty can be significantly reduced in future systems. For this reason, it could continually be the primary cost overrun factor.

Government contracting methods per se, would not appear to be responsible for overrunning the estimates. Generally, in a situation of little uncertainty, however, the firm-fixed price contract may be the most desirable to employ. On the other hand, where uncertainty is greater, cost control incentives might be attached. For their part in the acquisition process, the contract may merely provide an environment in which cost overrun can take place. CPFF tends to provide the best environment while FFP, the worst. The incentive contracts could supply a varying environment, depending on how well cost controls are applied to the process, and how effectively the "buy-in" tendency is controlled.

Overrun Factors in Cost Estimating Methods

Industrial Engineering Methods.--This method of cost estimating appears to be of most value where a clearly defined system is to be produced. Since each task from the lowest level of detail must be analyzed and aggregated, the inference is that industrial engineering could be best employed when development is fairly advanced. In the typical modern

weapons system, industrial engineering would tend to be subject to subsequent changes in design and performance specifications. Therefore, in early stages of the system acquisition, industrial engineering would not be of significant value in developing the initial systems cost estimates, except for duplication of components. Contractors tend to avoid this method.

It could tend to become an overrun factor if solely employed in the face of imminent technological change. Similarly, it could figure as an overrun factor in a situation where the whole turns out to be greater than the parts, as noted by Large.

Estimating by Analogy.--To employ analogy as a primary estimating tool, runs the risk as experienced by Douglas. In some cases, great similarities with past systems may produce an excellent cost estimate. However, unknowns and technological change entering the proposed system could greatly reduce the value of the analogy method and introduce great error. It could not be termed as inherently possessing the tendency to produce an overrun. It must depend on the particular circumstances and prior data base of the estimate.

Statistical Technique.--The danger is always present that data may not be related to a particular system. If there is no direct relationship, this estimating technique

could become a cost overrun factor of varying dimensions. Freund's admonition that any projection of past experience to the uncertain future is speculative and hazardous, is well taken.

Cost Estimating Methods in General.--As with the government contract, any estimating technique is influenced by the uncertainties of technology, time, and economic factors. Whether it is industrial engineering, analogy, or statistical, the method can be an overrun factor only to the extent that the method itself is faulty. Marshall and Meckling concede that it is not possible, in practice, to isolate the extent of the intrinsic cost estimating error. In relation to other factors, such as buy-in, estimating techniques of themselves, do not appear to be a prime overrun factor.

Overrun as a Function of Inflation

To examine a program such as the C-5A, inflation was conceded to contribute to the overrun. Yet, the range of estimates on exactly how much it added was great. These ranged from $204 million to $627 million. Such a range seems to indicate that the inflation overrun factor is not really identifiable. Expert testimony of Scherer and Fitzgerald tend to discount inflation as a prime factor in

overrun. If the rate of price increase is compared to the rate based on past trends, the difference constitutes overrun. The difference, even in periods of considerable inflation, such as 1966 to 1969, tends to be relatively small. It appears that inflation is definitely an overrun factor to the extent that price growth is not included in government contracts. However, this does not seem to be as large an item as commonly supposed.

Overrun Factor Interrelationships

Buy-In vs. Optimism

Both the Mark II and Skybolt programs resulted in overruns of considerable magnitude, yet the contractors were accused of different practices. Autonetics was said to have attempted a buy-in by submitting an apparently unrealistic low bid. On the other hand, Douglas made a very low bid on Skybolt and was thought to be overly optimistic. The difference between the two appears to be difficult to separate. It is possible that it is largely a matter of semantics. Yet, it could very well be based on the contractor intent. In order to further isolate overrun factors, it is inferred that the buy-in constitutes a deliberately low bid, while the Douglas Skybolt case is one of optimism based on overambitious development attempts. The study differentiates between the two on that basis.

Contracting and Estimating

Although contracting and estimating were examined as separate entities, they seem to be closely related to each other. The value of the contract, or whether or not the final cost equals the expected cost, is dependent on the initial cost estimate. While estimating may possess some not too clearly defined faults of itself, it seems to be inseparably attached to the contracting process. The cost overrun factor, therefore, seems to be a tendency or trend that was not, or could not be applied to the estimating method. The estimating method by itself, does not appear to constitute a serious overrun factor.

Cost Overrun Factors Summarized

As a result of the evidence, testimony, and cases examined, the following factors are set forth as the apparent prime overrun factors:

(1) Technological uncertainty may be the most serious causative agent. There is simply not a significant step that can be taken to eliminate it.

(2) An apparently strong contractor incentive to deliberately make a low estimate in order to buy-in on a program.

(3) The optimism that pervades initial program decision making, with a resulting unrealistically low contract bid.

(4) Simple economic inflation; and probably the least serious of any overrun factor.

Application of Overrun Factors to the Estimating Process

Three of four overrun factors cited are of a highly intangible nature. Buy-in and optimistic tendencies seem to be largely subjective and not readily adaptable to quantification. Technological uncertainty is an unknown of varying degrees.

This study has uncovered no relationships, either expressed or inferred, that would tend to show that overrun factors could eventually be applied to the estimating process.

The fourth factor, inflation, is in theory capable of being expressed in concrete terms. However, its complex interaction with the other factors make it extremely difficult to isolate. Apparently, general trends can be demonstrated, but exact definitions shall probably remain a part of the unknown.

Conclusion

Cost overrun, as a definite factor in system acquisition, has apparently been greatly oversimplified. Critics seem especially ready to cite the original cost estimate and compare this to the final system cost. The difference, or apparent overrun, is attributed to a variety of reasons, as previously examined. However, what is often stated to be

overrun is not really overrun. Original specifications are changed, or the concept of the program is altered. Changes and alterations have a tendency to change the total cost of the program. In other words, added program benefits can be equated with added increments of cost. The real cost overrun must be considered as the cost not associated with the change in program scope.

As increasingly complex systems are developed and produced, change appears to remain a persistent byproduct of future acquisitions. For this reason, the real cost overruns which may occur, might constitute the most elusive element in systems procurement.

APPENDIX A

DEPARTMENT OF DEFENSE INSTRUCTION 7000.2

Subject: Performance Measurement for Selected Acquisitions.

References:
(a) DOD Directive 7000.1, "Resource Management Systems of the Department of Defense," August 22, 1966
(b) DOD Directive 3200.9, "Initiation of Engineering and Operational Systems Development," July 1, 1965
(c) Armed Services Procurement Regulations (1963 Edition)
(d) MIL-STD-881 (to be published)

I. PURPOSE AND APPLICABILITY

This Instruction sets forth objectives and criteria and authorizes the publication of a guide, within the purview of reference (a), for the application of uniform DOD requirements for contractors' management control systems to selected Defense contracts. The provisions of this Instruction require the use of Cost/Schedule Control Systems Criteria (C/SCSC) in selected acquisitions and apply to all Military Departments and Defense Agencies (hereinafter referred to as DOD Components) which are responsible for acquisitions during engineering development, operational systems development and production.

II. SCOPE

A. The acquisitions governed by this Instruction will be in selected contracts within programs which are estimated in the Five Year Defense Program to require (1) a total cumulative financing for Research, Development, Test and Evaluation in excess of $25 million or (2) cumulative production investment in excess of $100 million. Firm fixed-price contracts will be excluded.

B. Subcontracts within applicable programs, excluding those that are firm fixed-price, will be selected for

application of these criteria by mutual agreement between prime contractors and the contracting DOD Component, according to the criticality of the subcontract to the program. Coverage of certain critical subcontracts may be directed by the DOD subject to the changes article of the contracts.

III. OBJECTIVE

A. DOD contractors should be continuously alert to advances being developed in management control systems to improve their contract performance, and to serve DOD and their best interests. It is an objective of this Instruction to bring to the attention of and encourage DOD contractors to accept and install management control systems and procedures which are most effective in meeting their requirements.

B. To provide an adequate basis for responsible decision making by both contractor management and DOD Components, contractors' internal management control systems must provide data which (1) indicate work progress, (2) properly relate cost, schedule, and technical performance, (3) are valid, timely, and auditable, and (4) supply DOD managers with a practicable level of summarization.

IV. POLICY AND PROCEDURES

A. Policy

It shall be the general policy to (1) require application of the DOD criteria as stated in Enclosure 1 to programs that are within the scope of Section II above, (2) require no changes in contractors' existing management control systems except those necessary to meet the criteria, and (3) require the contractor to use data from his own management control system in reports to the Government.

B. Procedures

The procedures contained herein will not be construed as requiring the use of specific systems, or changes in accounting systems which will adversely affect the equitable distribution of costs to all contracts. To avoid the proliferation of demands on contractors for demonstrations of their management systems, the criteria outlined in Enclosure 1 shall be incorporated in a basic agreement between the DOD and the contractor wherever feasible and will apply to more than one contract.

However, agreements concerning the acceptability and use of contractors' management control systems may be accomplished by the use of basic agreements, or through separate procurement contracts.

1. Basic Agreement

a. The use of a basic agreement contemplates the execution of a written instrument which includes C/SCSC and negotiated provisions which (1) reflect an understanding between the contractor and the DOD of the requirements of the DOD criteria, and (2) identify the specific system(s) which the contractor intends to use of applicable contracts with DOD Components. The basic agreement will include a written description of the system(s) validated in a demonstration review in sufficient detail to permit adequate surveillance by all interested parties. The use of a basic agreement in these circumstances is preferred where a number of separate contracts between one or more DOD Component(s) and the contractor may be entered into during the term of the basic agreement. It contemplates the delegation of authority to the cognizant DOD Component negotiating the basic agreement by all other DOD Components in order that it represent an understanding between the contractor and all prospective DOD contracting components. The basic agreements will be entered into pursuant to Section 3-410 of the Armed Services Procurement Regulation (reference (c)).

b. Action to develop a basic agreement may be initiated:

(1) Unilaterally by the contractor;
(2) By a DOD Component request to the contractor; and
(3) By either the contractor or the DOD Component, as the result of a contractor's response to a Request for Proposal (RFP).

c. A basic agreement may be arrived at after evaluation of the contractor's management control system in the context of the criteria, within the contractor's present or proposed operating environment and not necessarily in response to an RFP. The management control system(s) identified in the basic agreement will also be subjected to a demonstration review which may occur within the contractor's present environment, or in conjunction with the contractor's implementation of a separate DOD procurement contract.

2. Separate Procurement Contracts

As a result of either the requirement normally placed in an RFP or an action initiated by DOD Components, the contractor will provide a response which describes the integration of the basic subsystems to provide control of cost, schedule, and technical performance. This involves:

a. Evaluation.--The contracting DOD Component will conduct a design review as a part of normal procurement procedures to insure that the systems meet established criteria. When the systems have been evaluated and the contract awarded, the contracting DOD Component will notify the contractor of the results.

b. Demonstration.--DOD personnel will conduct an in-plant demonstration review of the contractor's management control systems. The purpose of systems demonstrations is to verify that the contractor is operating systems which meet the criteria. Upon completion of this demonstration, a written description of the system validated will be provided by the contractor in sufficient detail to permit adequate surveillance.

3. Demonstration Teams

a. The team conducting a demonstration review will ordinarily include representatives from the Army, Navy, Air Force (except where a Service requests nonparticipation due to noninvolvement), and the cognizant Defense Contract Audit Agency (DCAA) Auditor. The contracting or cognizant DOD Component will provide the team leader and will be responsible for all matters concerning the conduct of the demonstration review.

b. A detailed discussion of the team composition, tests, and guidance for the conduct of the review is contained in the Guide for Performance Measurement established under Section VI below.

4. Re-examination

a. In the event the contractor's system fails to pass the demonstration review, the cognizant DOD Component will discuss the specific shortcomings with the contractor and require the contractor to submit proposals for correcting deficiencies. Subsequent to official notification by the

cognizant DOD Component of a failure, the portion(s) of the management control system that failed may be subjected to a follow-up review. Specific guidance and procedures concerning determination and resolution of failures are contained in the Guide for Performance Measurement.

b. Upon successful completion of demonstration review, contractors will not be subjected to re-examination (other than through normal surveillance), unless there are positive indications that the contractor's system no longer meets the criteria.

V. RESPONSIBILITIES

The DCAA will review the contractor's accounting system and determine the accuracy and reliability of the financial data contained in the reports prepared from the contractor's systems and reported data will be accomplished by the cognizant plant representative. The cognizant auditor and the plant representative will collaborate in reviewing areas of joint interest.

A. The surveillance reviews will consist of (1) recurring evaluations of the effectiveness of the contractor's policies and procedures to produce valid data consistent with the intent of this Instruction, and (2) selective tests of reported data.

B. The cognizant auditor will submit a formal report of any deficiencies that cannot be resolved with the contractor, to the contracting DOD Component(s) through the local plant representative.

VI. GUIDE

A. The office of the Assistant Secretary of Defense (Comptroller) (OASD(C)) will publish, revise as necessary, and distribute the Guide for Performance Measurement separately from this Instruction.

B. The OASD(C) will maintain surveillance over the procedures prescribed in the Guide for Performance Measurement and insure implementation and continuous operation in a uniform manner throughout the Department of Defense.

C. Until the Guide for Performance Measurement is published, application of the criteria to ongoing or proposed programs

and associated reporting requirements will be subject to prior approval by the Assistant Secretary of Defense (Comptroller) (ASD(C)) or his designee for the purpose, with the concurrence of the Director of Defense Research and Engineering and the Assistant Secretary of Defense (Installations and Logistics).

VII. EFFECTIVE DATE AND IMPLEMENTATION

This Instruction is effective immediately. Two (2) copies of the proposed implementation documents will be forwarded to the ASD(C) within ninety (90) days after the date of this Instruction. Implementing instructions will not be published until thirty (3) days after their submission to ASD(c) for their review.

R. N. ANTHONY,

Assistant Secretary of Defense (Comptroller).

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